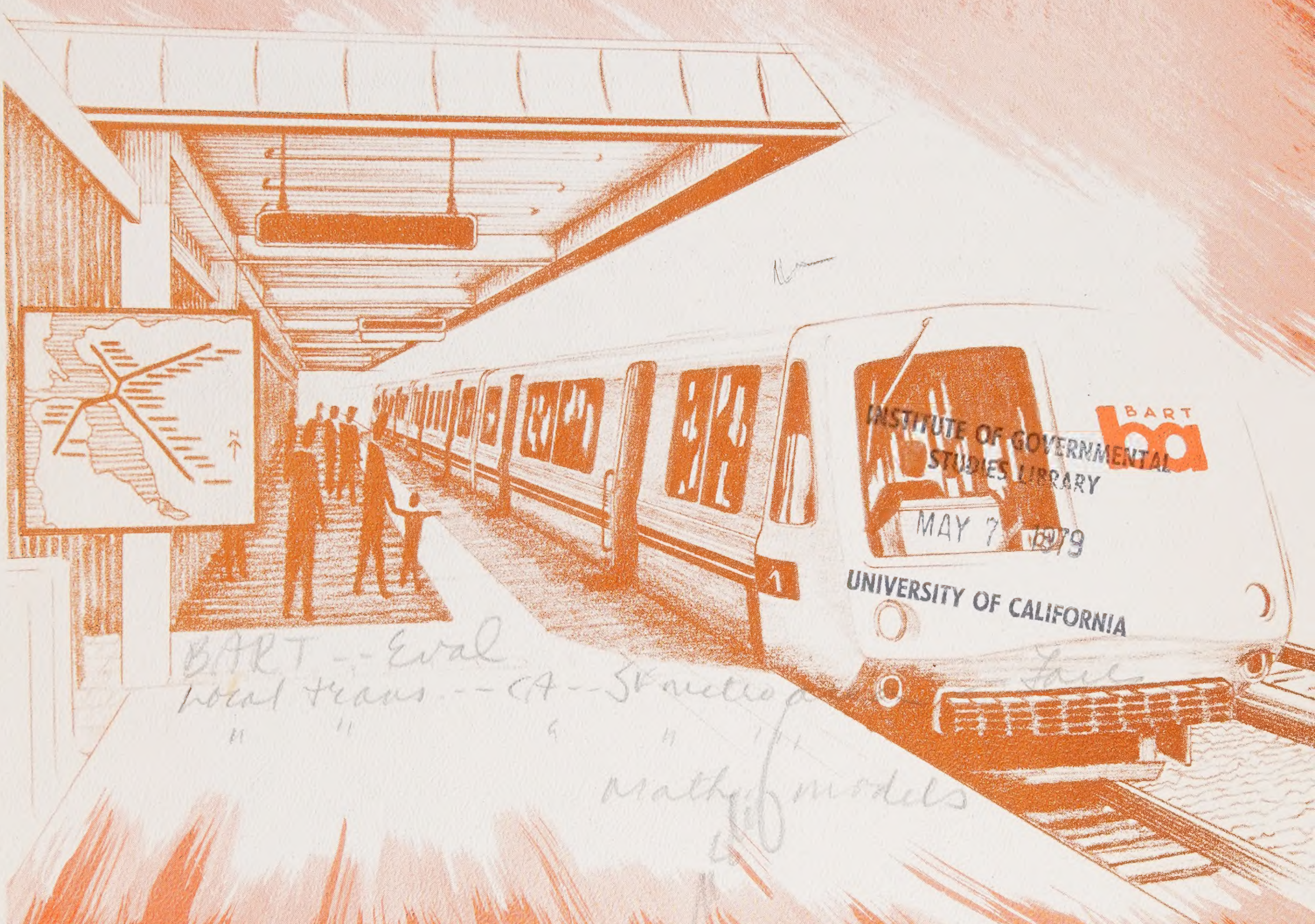
bart
impact
program

EXPLORATORY NETWORK ANALYSES OF BART'S IMPACTS ON ACCESSIBILITY



BART -- Eval
Local trans. -- CA --
math models

working paper

The BART Impact Program is a comprehensive, policy-oriented study and evaluation of the impacts of the San Francisco Bay Area's new rapid transit system (BART).

The program is being conducted by the Metropolitan Transportation Commission, a nine-county regional agency established by state law in 1970.

The program is financed by the U. S. Department of Transportation, the U. S. Department of Housing and Urban Development, and the California Department of Transportation. Management of the Federally funded portion of the program is vested in the U. S. Department of Transportation.

The BART Impact Program covers the entire range of potential rapid transit impacts, including impacts on traffic flow, travel behavior, land use and urban development, the environment, the regional economy, social institutions and life styles, and public policy. The incidence of these impacts on population groups, local areas, and economic sectors will be measured and analyzed. Finally, the findings will be interpreted with regard to their implications for the planning of transportation and urban development in the Bay Area and other metropolitan areas.

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BART IMPACT PROGRAM

EXPLORATORY NETWORK ANALYSES OF BART'S IMPACTS ON ACCESSIBILITY

OCTOBER 1977
(REVISED)

WORKING PAPER

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PREPARED FOR

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AND

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WASHINGTON, D.C.

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NOTICE

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Transportation System and Travel Behavior Project

Exploratory Network Analyses of BART's Impacts on Accessibility
Prepared by
Peat, Marwick, Mitchell & Co.

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16. Abstract
BART, the 71-mile Bay Area Rapid Transit System, serving San Francisco, Oakland, and other cities and communities, is the first regional-scale rapid transit system to open in the United States in over 50 years. Service began in 1972. This report is one of a series assessing the impact of BART on transportation and travel in Bay Area.

Accessibility measures were based on estimates of zone-to-zone travel times and transit fares derived from computer network representations of the Bay Area transportation system. Comparisons are made for the 1971 pre-BART, 1976 with-BART, and 1976 hypothetical "no-BART" transit networks and the 1976 highway network. Peak period travel times were compared for selected zones representing typical home-to-work trips, while off-peak comparisons were made for selected shopping destinations. Weighted travel times were also computed based on the estimated volume of trips between zones.

As it was designed to, BART provides the most significant travel time improvements for long-distance, downtown-oriented trips by public transit, especially from outlying areas that would have relatively poor transit service without BART. However, for most trips, door-to-door times by BART are still much longer than times for the same trips by automobile, even at periods of peak highway congestion.

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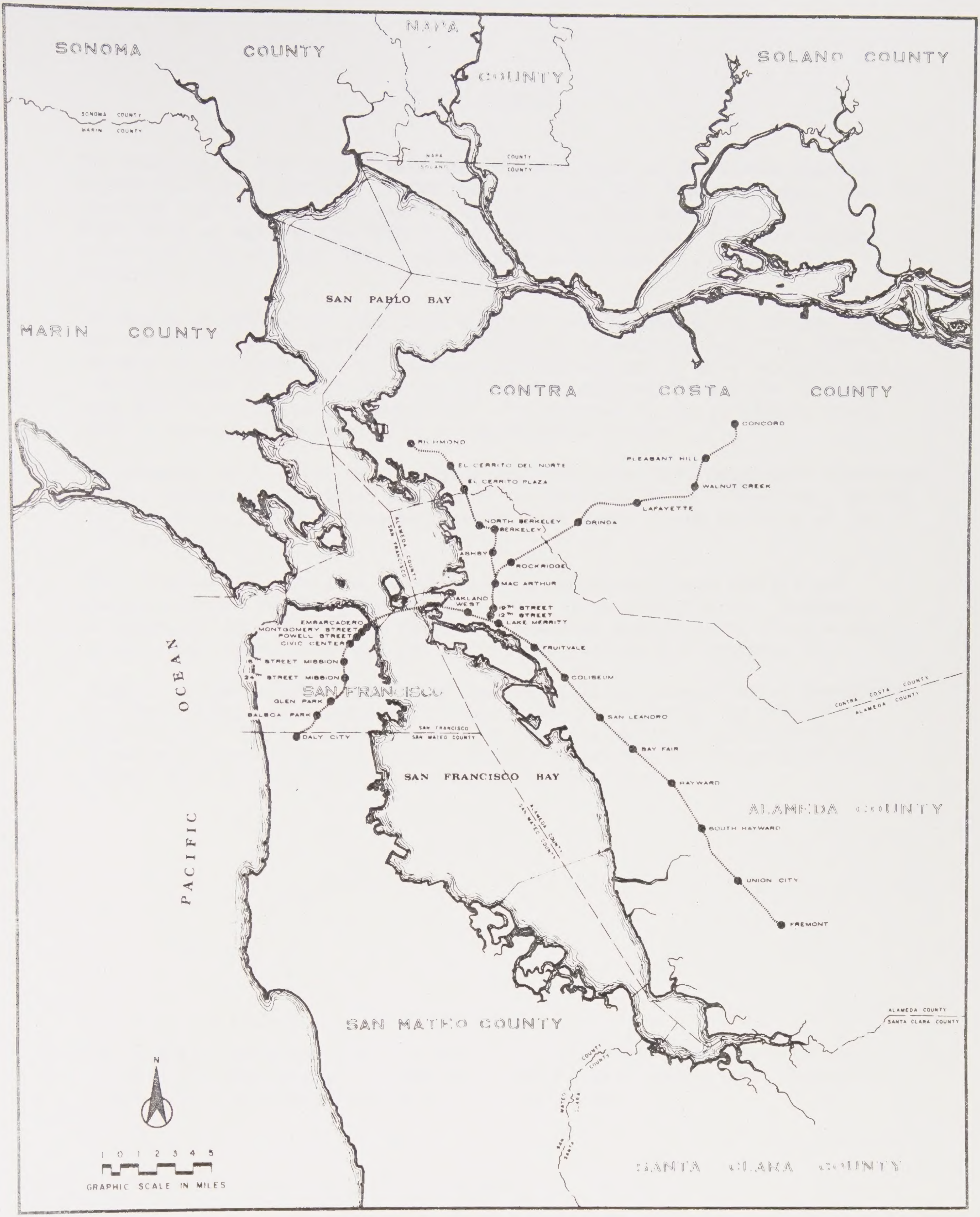

BAY AREA RAPID TRANSIT SYSTEM

PEAT, MARWICK, MITCHELL & CO.
SAN FRANCISCO

PREFACE

The analyses in this report were undertaken as part of the Transportation System and Travel Behavior (TSTB) Project of the BART Impact Program. The networks and fare matrices used in the analyses were developed by JHK & Associates as part of the TSTB Project and are documented in other project reports.* The accessibility analyses were undertaken by Peat, Marwick, Mitchell & Co.

It should be emphasized that these analyses are exploratory in nature. They are intended only to provide some preliminary information regarding BART's impacts on accessibility to selected destinations and to give insights into the usefulness of particular kinds of network analyses as a means of assessing BART's impacts on accessibility. The analyses do not purport to treat BART's accessibility impacts in a comprehensive manner.

In November 1975, after this analysis was completed, BART fares were increased, with a new maximum of $1.45 instead of the previous $1.25. Therefore, actual BART fares in 1976 were somewhat greater than shown in the analyses of the 1975 report.

This October 1977 revision incorporates two appendixes that clarify and expand upon the initial 1975 analysis. The first describes the "No-BART alternative" transit system; the second analyses accessibility differences between the actual with-BART and the hypothetical no-BART systems.

Thanks are due to staff members of the Metropolitan Transportation Commission for their advice and assistance in developing the networks and preparing this report. The assistance of Mr. Tom Narrigan and Mr. Joel Markowitz is especially acknowledged. However, responsibility for the contents of the report lies entirely with Peat, Marwick, Mitchell & Co.

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*DD-3-3-75: Development of Pre-BART (1971) Highway and Transit Networks.
DD-5-3-75: Development of Post-BART (1976) Highway and Transit Networks.
DD-6-3-75: Development of Transit Fare Matrices.

SUMMARY AND CONCLUSIONS

Objectives

The purpose of this study was twofold:

1. To make a preliminary assessment of BART's impact on regionwide accessibility, and

2. To evaluate the use of network-based accessibility measures as an impact analysis technique.

Methodology

Two types of accessibility measures were employed. The first was based on estimates of zone-to-zone travel times and the second on estimated interzonal transit fares. In each case, the measures were expressed in the form of simple "accessibility indices," weighted by the size and characteristics of the resident population in the origin zone. All indices were of either the "one-to-one" (i.e., one origin-zone to one destination-zone) or the "many-to-one" variety (i.e., all origin-zones to one destination-zone). The analysis covered all residential origin zones in a "BART impact area" defined in this study as that geographic region covering Alameda, San Francisco, and Contra Costa Counties, plus the northern portion of San Mateo County.

Representative samples of three types of destination zones were analyzed: (1) employment locations, (2) major shopping areas, and (3) selected health-care facilities. Most destination zones were chosen to include one or more BART stations.

Travel time data were derived from "pre-BART" and "post-BART" highway and transit networks developed for the years 1971 and 1976, respectively. Transit fare data were based on interzonal transit fare matrices constructed for the same two years. All demographic information was based on updated estimates of 1970 U.S. Census information. BART's impact on accessibility was then assessed by comparing the values of equivalent accessibility indices for the pre-BART and post-BART condition.

BART's Impact on Accessibility to Employment

Three employment centers were analyzed: the Central Business Districts (CBDs) of Oakland and San Francisco, and an outlying employment center, the General Motors (GM) Plant in Fremont.

<u>Impact on Peak Period Transit Travel Time for General Population</u>. For the study area population as a whole, BART reduced average peak period transit travel times to the San Francisco and Oakland CBDs by approximately 11

minutes and 18 minutes, respectively. This represents reductions of roughly 21% and 29% from the pre-BART (1971) condition. For the General Motors Plant the impact was considerably higher. In this case, the average reduction in peak period transit travel time was 62 minutes, equivalent to 47% of the pre-BART value.

Impact on Low-Income and Minority Residents. Although substantial, average peak period savings in transit travel time for low-income and minority residents to the two CBDs were lower than for the population as a whole. Average transit travel times for low-income residents to the central areas of San Francisco and Oakland decreased by approximately 9 and 15 minutes, respectively, equivalent to savings of 18% and 27% over pre-BART levels. For ethnic minorities, the equivalent average savings were 6 and 12 minutes, representing reductions of roughly 15% and 24%, respectively. In the case of the Fremont GM Plant, the average transit time savings due to BART for low-income (63 minutes or 48%) and minority groups (64 minutes or 48%) were both approximately equal to the impact for the population as a whole.

Two factors appear to account for these results. Firstly, the major time savings due to BART accrue for long trips. A large number of low-income and minority residents live close to the centers of Oakland and San Francisco. Hence, their potential time savings due to BART are relatively low. Secondly, the level of pre-BART transit service in many of these close-in communities was already relatively high, and certainly higher than the service to the outlying suburbs now served by BART. In particular, in 1971 the Fremont area had only infrequent bus service. BART, therefore, has had a major impact in improving transit accessibility to this area.

Impact on Average Transit Fares. Over the period 1971-1976, the average transit fare to the San Francisco CBD increased by 32% (21¢) for the population as a whole. Correspondingly, the average transit fare to the Oakland CBD increased by 19% (or 13¢) for the general population. The fare increases to these CBDs for the minority and low-income populations do not significantly differ from the increases for the general population. In interpreting these figures, it should be borne in mind that MUNI and AC Transit bus fares remained essentially constant over the period in question. Thus, the increased fares largely result from the potential choice of BART rather than bus.

Comparison of Post-BART Highway and Transit Travel Times. Average peak period highway and transit travel times to the San Francisco CBD are essentially the same for the post-BART condition. In contrast, however, average peak period transit travel times to the Oakland CBD and Fremont are higher than the equivalent average highway travel times. In the case of the Oakland CBD, the average transit travel time is 12 minutes longer for the general population and 13 minutes longer for minority residents; for the Fremont GM Plant, the equivalent figures are 28 and 23 minutes respectively.

In interpreting these data, it should be borne in mind that virtually all San Francisco CBD commuters travel with the predominant peak period traffic flow, and hence experience significant traffic congestion and delay. A high porportion of Oakland CBD and Fremont commuters travel in the direction opposite to the predominant traffic flow; they, therefore, experience less congestion and can travel at higher speeds.

In general, it can be stated that BART significantly improved the competitive position of transit vis-a-vis highway travel for peak period commuting to the three employment areas analyzed. Prior to the introduction of BART service, time savings for peak period highway compared with transit travel to the three areas was roughly twice that which now exists.

BART's Impact on Accessibility to Shopping Facilities

Three shopping destinations were studied: the CBDs of San Francisco and Oakland and the Bay Fair Shopping Center in San Leandro adjacent to the Bay Fair BART Station.

Impact on Off-Peak Transit Travel Times. Comparison of pre-BART and post-BART transit off-peak travel times yields conclusions similar to those reached in the analysis of employment accessibility. BART decreased average transit travel times for the overall population to the San Francisco CBD, the Oakland CBD, and the Bay Fair Center by 16, 18, and 28 minutes (or 26%, 29%, and 31%), respectively. The minority population experienced reductions in average travel times of 8 minutes to the San Francisco CBD, 11 minutes to the Oakland CBD, and 23 minutes to the Bay Fair Shopping Center (or 17%, 22%, and 28%, respectively). Travel times generally decreased more in the off-peak period than in the peak period. This is largely due to the improved frequency of transbay service provided by BART in the off-peak period.

Impact on Average Transit Fares. Introduction of BART service increased average off-peak transit fares to the CBDs of San Francisco and Oakland and to Bay Fair Shopping Center by 15¢, 9¢, and 13¢, (or 21%, 12%, and 16%), respectively, for the general population; and by 14¢, 7¢, and 18¢ (or 28%, 12%, and 26%), respectively, for the minority population.

BART's Impact on Accessibility to Health-Care Facilities

Three major hospital facilities were included in the analysis: Oakland Kaiser Hospital, the University of California Medical Center in San Francisco, and San Francisco General Hospital.

Impact on Transit Travel Time. A comparison of pre-BART and post-BART transit travel times shows that accessibility to these three hospitals improved mainly for residents of zones located over an hour away. Since the

Kaiser Hospital group has clinics and hospitals in other parts of the Bay Area, and the University of California Medical Center and San Francisco General Hospital tend to serve the day-to-day medical needs of San Francisco residents (for which trips might be made by transit), it would appear that BART has not significantly improved the transit accessibility of the population to these medical facilities.

Impact of Automobile Availability on Transit Accessibility via BART

Lack of an automobile to drive to the nearest BART station decreases average post-BART employment and shopping accessibilities via transit for the overall population. The same is true, though to a slightly smaller extent, for the low-income population. Lack of adequate automobile access does not significantly affect current transit accessibilities to either employment or shopping for minority residents. This is most probably because a high proportion of minority residents live either in areas well served by bus access to BART or within walking distance of the BART system.

Interpretation of Findings

The findings outlined above must be interpreted with some caution. Their accuracy is heavily dependent on the realism and accuracy of the computer-coded highway and transit fare matrices. Aside from coding errors (which are considered minimal) the major sources of potential error in this regard are:

- Representation of access times to and from transit lines
- Treatment of intrazonal highway travel times
- Procedures for minimum path selection
- Computation of specific zone-to-zone transit fares

These factors, though they may give rise to specific errors for a particular zone or zonal-pair, should not be such as to seriously effect the overall pattern of the results. Similarly, it is considered that errors in the estimation of current zonal-level population characteristics, though they may be significant in certain specific cases, should not seriously influence the overall results.

The results presented here are exploratory only. They were designed primarily to examine the efficacy of the computational procedures involved, rather than to generate extensive, substantive findings. They are based on only a limited sample of destination sites, selected so as to maximize BART's potential impact and accessibility. As such, they hold true in themselves but should not in their present form be considered generalizable to the region as a whole.

Finally, it should be stressed that all the accessibility measures discussed above deal with potential rather than actual travel. To be interpreted fully, they must be examined in the light of actual travel demand. For example, a significant decrease in travel time by transit from San Francisco to the Fremont GM Plant is meaningful only if a substantial number of workers (or potential workers) at that plant live in San Francisco.

Methodological Conclusions

Based on the results of this exploratory study, it appears that selective extension of network-based accessibility analyses would be warranted in subsequent phases of the TSTB Project. The methodology appears to provide an accurate picture of BART's impacts on overall, areawide accessibility. It does not, however, necessarily provide an accurate picture of specific localized effects.

The results of the analysis suggest (not surprisingly) that the major impact of BART on accessibility is likely to be for origins and destinations which are relatively close to BART stations. For points situated significant distances from the BART System, the impact of BART on accessibility is likely to be extremely small. This suggests that major emphasis should be placed in any further analysis on extension of the "many-to-one" calculations outlined here. This should include consideration of additional destination points, both for the same activities as were included in this exploratory study and for selected additional activities, e.g., education and recreation. In this regard, an attempt should be made to match individual employment locations with the corresponding labor force.

It is also recommended that consideration be given to a limited set of "one-to-many" and "many-to-one" analyses, with the set of destination zones being restricted to those areas well served by BART. However, it should be emphasized that meaningful performance of both "one-to-many" and "many-to-one" analyses is necessarily dependent to a large degree on the availability of destination-oriented activity data (e.g., employment by place of work). The availability of such information is currently extremely limited.

It is not recommended that any regionwide many-to-many analyses be undertaken. Similarly, it is not recommended that any significant resources be allocated to the consturction of accessibility indices significantly more complex than those used in this study.

No attempt was made here to assess the value of accessibility measures based on the use of augmented network data, that is, measures of system characteristics other than travel time or cost. However, it is recommended that any such analyses be restricted to a limited set of origin and destination zones clustered within one or more corridors serviced by BART.

Finally, it is recommended that accessibility analyses for comparisons of BART and hypothetical no-BART networks only be undertaken if and when the appropriate no-BART network(s) have been developed for behavioral modeling purposes. It is not recommended that no-BART networks be developed specifically for the purposes of accessibility analysis.*

* See Appendix D

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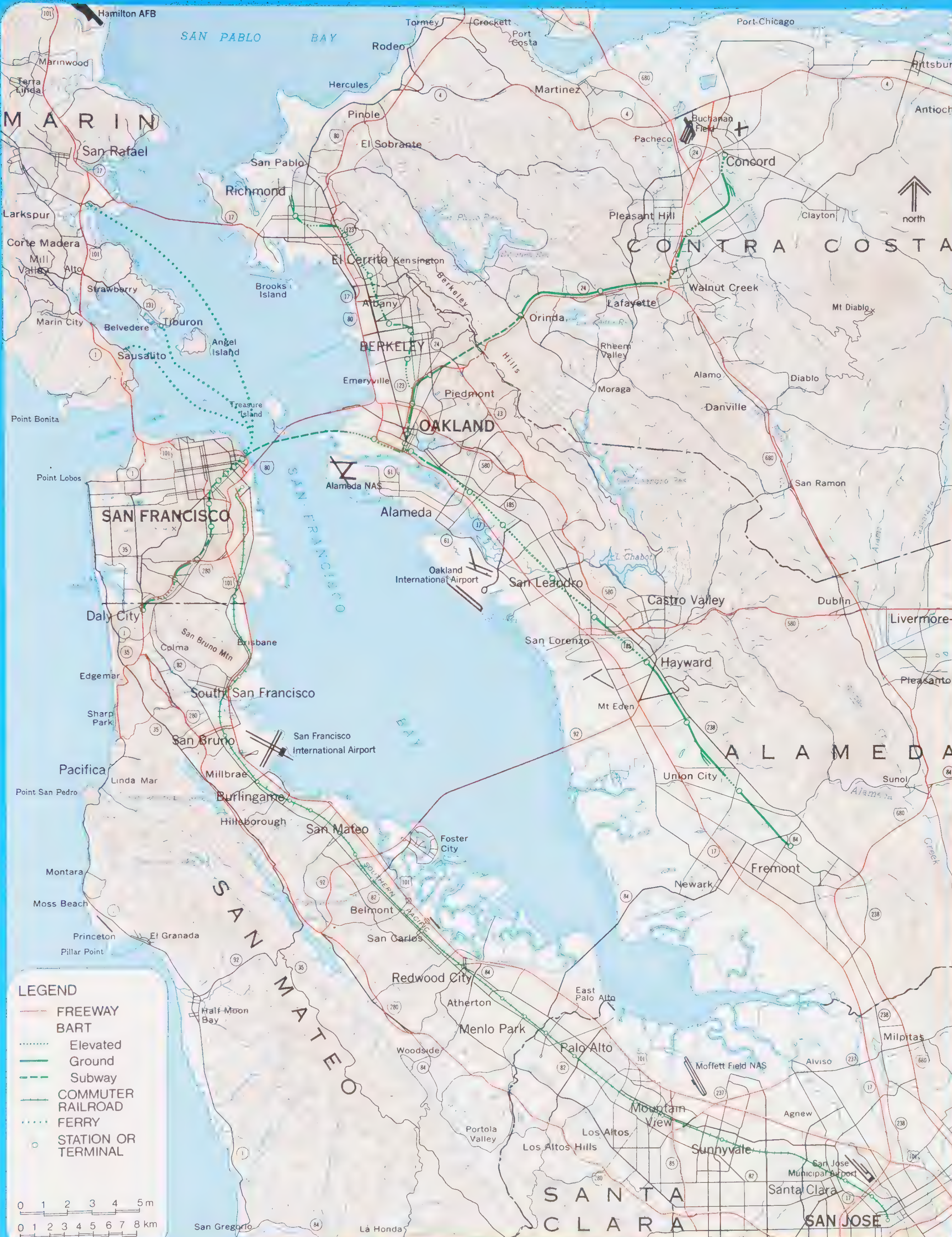

SAN FRANCISCO BAY REGION
CENTRAL AREA

Metropolitan Transportation Commission

BART: The Bay Area Rapid Transit System

Length: The 71-mile system includes 20 miles of subway, 24 miles on elevated structures and 27 miles at ground level. The subway sections are in San Francisco, Berkeley, downtown Oakland, the Berkeley Hills Tunnel and the Transbay Tube.

Stations: The 34 stations include 13 elevated, 14 subway and 7 at ground level. They are spaced at an average distance of 2.1 miles: stations in the downtowns are less than one-half mile apart, while those in suburban areas are two to four miles apart. Parking lots at 23 stations have a total of 20,200 spaces. There is a fee (25 cents) at only one of the parking lots. BART and local agencies provide bus service to all stations.

Trains: Trains are from 3 to 10 cars long. Each car is 70 feet long and has 72 seats. Top speed in normal operations is 70 mph with an average speed of 38 mph including station stops. All trains stop at all stations on the route.

Automation: Trains are automatically controlled by the central computer at BART headquarters. A train operator on board each train can override automatic controls in an emergency.

Magnetically encoded tickets with values up to $20 are issued by vending machines. Automated fare gates at each station compute the appropriate fare and deduct it from the ticket value.

Fares: Fares range from 25 cents to $1.45, depending upon trip length. Discount fares are available to the physically handicapped, children 12 and under, and persons 65 and over.

Service: BART serves the counties of Alameda, Contra Costa and San Francisco, which have a combined population of 2.4 million. The system was opened in five stages, from September 1972 to September 1974. The last section to open was the Transbay Tube linking Oakland and the East Bay with San Francisco and the West Bay.

Routes are identified by the terminal stations: Daly City in the West Bay, Richmond, Concord and Fremont in the East Bay. Trains operate from 6:00 a.m. to midnight on weekdays, every 12 minutes during the daytime on three routes: Concord-Daly City, Fremont-Daly City, Richmond-Fremont. This results in 6-minute train frequencies in San Francisco, downtown Oakland and the Fremont line where routes converge. In the evening, trains are dispatched every 20 minutes on only the Richmond-Fremont and Concord-Daly City routes. Service is provided on Saturdays from 9 a.m. to midnight at 15-minute intervals. Future service will include a Richmond-Daly City route and Sunday service.* Trains will operate every six minutes on all routes during the peak periods of travel.

Patronage: Approximately 146,000 one-way trips are made each day. Approximately 200,000 daily one-way trips are anticipated under full service conditions.

Cost: BART construction and equipment cost $1.6 billion, financed primarily from local funds: $942 million from bonds being repaid by the property and sales taxes in three counties, $176 million from toll revenues of transbay bridges, $315 million from federal grants and $186 million from interest earnings and other sources.

March 1978

*Sunday service began in July, 1978

I. INTRODUCTION

The Transportation System and Travel Behavior (TSTB) Project Research Plan[1]* identifies two important accessibility issues to be investigated in the Project:

1. Has BART increased accessibility for the Bay Area population to activities such as jobs, health care, education, recreation, and shopping?

2. Has BART had <u>differential</u> impacts on the accessibility of various population segments? This issue considers the "equity" of BART's impacts, or the way in which BART's costs and benefits are distributed throughout the population.

In this report, the term "accessibility" means the ease with which one could, potentially, travel to desired activities, and ease of travel is defined in terms of travel "impedances." These impedances might be simple measures of travel time and cost--like those included in conventional transportation network representations, or measures such as reliability and safety, which are not included in conventional network representations. It should be emphasized that accessibility is used here to define potential travel. Reductions in travel impedances are translated into traveler benefits only insofar as travelers actually use the improved transportation service.

Objectives and Scope

The accessibility analyses in this paper are exploratory and have the objectives of (1) providing preliminary information on BART's impacts on accessibility to selected destination zones; and (2) examining the extent to which comparisons of simple zone-to-zone accessibility measures, derived from conventional network representations, can provide useful information on BART's impacts.

Highway and transit networks representing the transportation system before and after BART are compared to study the extent of BART's accessibility impacts on the total population. Differential BART impacts on various population groups are assessed based on comparisons of zone-to-zone network travel times and costs. No regionwide accessibility indices are included and analyses are confined to changes in travel impedances for specific population groups and for selected destination zones. Population groups are defined in terms of income, ethnic identification, age, and automobile availability. Destination zones include major workplace locations, shopping facilities, and medical facilities.

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*Numbers refer to references in Appendix A.

Two principal sets of network impedance comparisons are made:*

1. Expected impedances of the 1976 transit system, including BART, are compared to those of the transit system before BART opened (1971).

2. Expected impedances of the 1976 transit system are compared to those of the 1976 highway system.

Comparisons are also made for two versions of the 1976 transit network. One version assumes that the automobile is available as an access mode to the BART station or bus stop; the other assumes no automobile is available. All comparisons are based on travel time and travel cost impedances determined from conventional transit and highway networks. Both peak and off-peak travel times and costs are utilized, as appropriate.

Overview of this Paper

Chapter II describes the analytical methodology used in this study. It covers the criteria used to select the study area and activity centers and describes the data base of the analyses. Chapters III and IV discuss the results of the exploratory accessibility analyses and present some preliminary conclusions on BART's impacts on the accessibility of various population groups. Chapter V investigates the applicability of network analyses to a study of BART's impacts on accessibility in terms of the networks, the data base, and the analytical approach. Shortcomings of the analytical methodology and possible areas for further work are also discussed.

* A third comparison with the hypothetical 1976 no-BART transit system is described in Appendix D.

II. ANALYTICAL METHODOLOGY

Selection of the Study Area

The study focuses on the BART Impact Area--the geographic region from which BART travelers are drawn and within which BART's impacts on accessibility may be significant. For purposes of this study, the impact area includes the three counties (Alameda, Contra Costa, and San Francisco) in the BART District and northern San Mateo County where many residents ride the BART line from Daly City. Figure 1 is a map of the study area.

Computation of Accessibilities

Accessibility measures may be computed in many different ways. For the purposes of this exploratory analysis, four simple types of measures were considered. Two of these were actually employed in the final computations.

The basic measures considered, in approximately increasing order of complexity, were:

1. "One-to-One" Measures. These are estimates of travel impedance between a specific "origin" zone and a specific "destination" zone--e.g., the travel cost between a simple, typical "residential" zone in Walnut Creek and a simple, typical "employment" zone in the San Francisco CBD. Mathematically, this may be represented as "I_{ij}", where the subscripts "i" and "j" refer respectively to specific origin and destination zones and "I_{ij}" represents the selected impedance estimate between the centroids of zones "i" and "j".

2. "Many-to-One" Measures. These are estimates of average travel impedance between all "origin" zones of a particular type and a particular "destination" zone--e.g., the average travel time between all "residential" zones within the BART service area and a typical "employment" zone in the San Francisco CBD. In general terms, this may be represented mathematically as "$I_{\Sigma,j}$", where:

$$I_{\Sigma,j} = \frac{1}{n} \Sigma_{i=1}^{n} (I_{i,j})$$

"$I_{i,j}$" is as defined above,
and "n" is the number of origin zones.

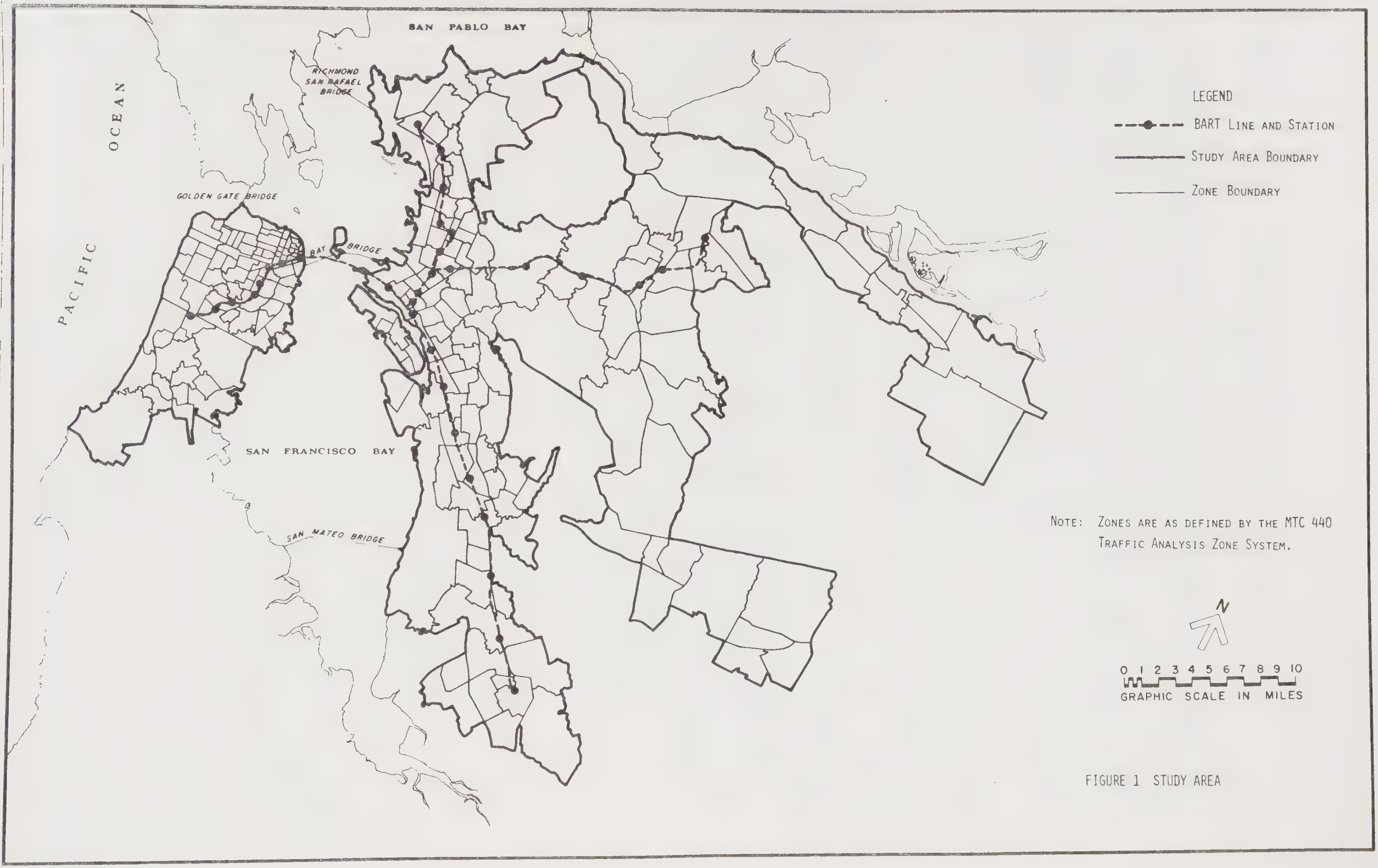


FIGURE 1 STUDY AREA

3. "One-to-Many" Measures. These measures are formed by the opposite calculation to Item 2 above, and represent an estimate of the average travel impedance from one specific "origin" zone to all "destination" zones of a particular type, e.g., the average travel time between a particular "residential" zone in Walnut Creek and all potential "employment" zones within the BART service area. Conceptually, this may be represented as "$I_{i,\Sigma}$", where:

$$I_{i,\Sigma} = \frac{1}{m} \sum_{j=1}^{m} (I_{i,j})$$

"$I_{i,j}$" is as defined above,
and "m" is the number of destination zones.

4. "Many-to-Many" Measures. These represent the combination of Items 2 and 3 above into an average estimate of the travel impedance between all "origin" zones of a particular type and all "destination" zones of a certain type--e.g., the average travel cost between all "residential" zones and all "employment" zones in the BART service area. Mathematically, this may be represented as "$I_{\Sigma,\Sigma}$", where:

$$I_{\Sigma,\Sigma} = \frac{1}{mn} \sum_{i=1}^{n} \sum_{j=1}^{m} (I_{i,j})$$

and "n", "m", "I_{ij}" are as defined above.

Figure 2 illustrates the computations involved for each of the four basic accessibility measures. These basic accessibility measures may be elaborated in several ways. In the present exploratory analyses, in order to reduce unnecessary computational costs, only Measures 1 and 2 were investigated. These were constructed as follows. All "One-to-One" calculations were based on straightforward estimates of interzonal "travel time" and "cost." These were derived, respectively, from estimated zone-centroid to zone-centroid network travel times and zone-to-zone transit fares.

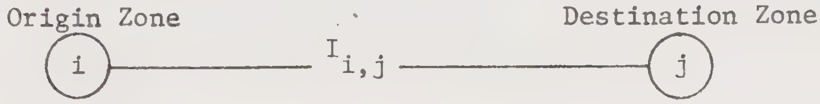
The "Many-to-One" calculations were based on the travel time or cost between all origin zones and a selected destination zone weighted by the population of the origin zone. That is:

$$I_{\Sigma,j} = \frac{\sum_{i=1}^{n} (p_i^k \, t_{i,j})}{\sum_{i=1}^{n} (p_i^k)}$$

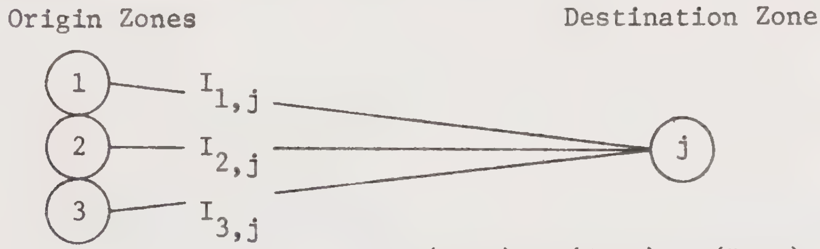
FIGURE 2

CALCULATION OF BASIC ACCESSIBILITY MEASURES

1. One-to-One Measures

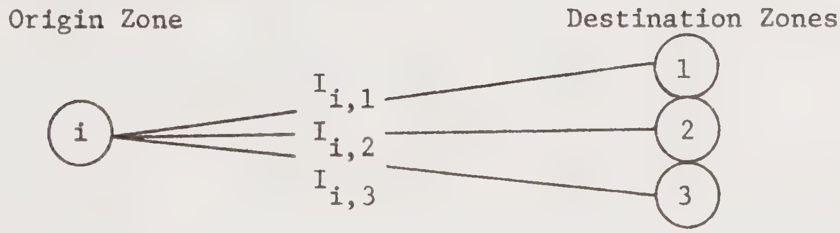


2. Many-to-One Measures



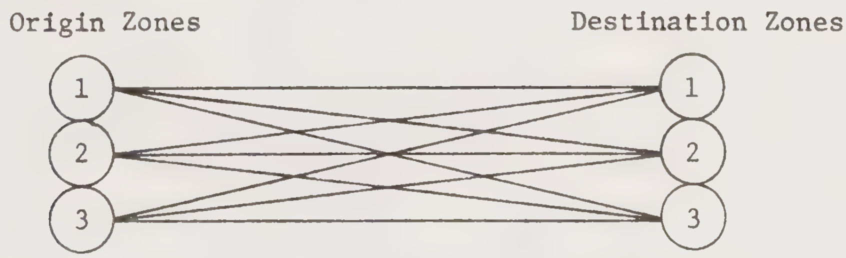
$$I_{\Sigma,j} = \frac{(I_{1,j}) + (I_{2,j}) + (I_{3,j})}{3}$$

3. One-to-Many Measures



$$I_{i,\Sigma} = \frac{(I_{i,1}) + (I_{i,2}) + (I_{i,3})}{3}$$

4. Many-to-Many Measures



$$I_{\Sigma,\Sigma} = \frac{(I_{1,1})+(I_{1,2})+(I_{1,3})+(I_{2,1})+(I_{2,2})+(I_{2,3})+(I_{3,1})+(I_{3,2})+(I_{3,3})}{9}$$

where: $t_{i,j}$ = travel time (or cost) between zone i and zone j

p_i^k = population of type k in zone i

Note that provision is made in the calculation to stratify the population in zone "i" by selected population categories, such as income class, ethnic identification, etc. In addition, calculations were made of the cumulative percentage of the total service area population in a particular category "k" which lay within a given travel time or transit cost of each specified destination zone.

Selection of Activity Centers

Although accessibility changes in many zones and activity centers could be of interest, the scope of this exploratory study only allows examination of selected zones containing three major activities: employment, shopping, and health care. For each activity, three destination zones are investigated in detail. These zones represent an important location in the Bay Area for one of the three activities:

- Employment Activities. The zones investigated contain the San Francisco central business district (CBD), Oakland CBD, and the General Motors Plant in Fremont.

- Shopping Activities. The zones investigated contain the San Francisco CBD, Oakland CBD, and Bay Fair Shopping Center in San Leandro.

- Medical and Health Care Activities. The zones investigated contain the Oakland Kaiser Permanente Medical Center, the University of California Medical Center in San Francisco, and San Francisco General Hospital.

In general, these zones were deliberately selected because they are well served by BART.* If the analyses show no significant changes in accessibility

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*The downtown San Francisco and downtown Oakland zones are each served by two BART stations; the Bay Fair shopping center is immediately adjacent to the Bay Fair BART Station; Kaiser Medical Center in Oakland is in the same traffic zone as the MacArthur BART Station (and is served by AC Transit feeder bus). The zone containing San Francisco General Hospital is not served directly by BART, but is served by MUNI feeder bus from the 24th Street-Mission Station. The University of California Medical Center in San Francisco is not well served by BART; nor is it well connected by bus. The zone containing the General Motors Plant in Fremont is about five miles from the Fremont BART Station, but there are bus services connecting the plant and the station.

to these zones, one can conclude that BART has no impact on accessibility in the entire impact area.

Description of Data Base

The data base in this study consists of two components: network data and zonal socioeconomic data.

Network Data. The following sets of highway and transit networks[2,3] were developed in the TSTB Project based on the Metropolitan Transportation Commission's (MTC) 440-zone regional traffic system.

Pre-BART

1. 1971 Highway Network

2. 1971 Transit Network

Post-BART

3. 1976 Highway Network (as it is expected to exist)

4. 1976 Transit Network (including BART)

Using these networks, travel time skim trees were computed for the highway and transit systems and fare matrices were computed for the transit systems.

The travel time trees and fare matrices were developed independently. The travel time trees were built using a computed minimum time path, whereas the fare matrices were constructed from paths selected by the network analyst based on his knowledge of the Bay Area transit system.[4] Therefore, the two paths may differ.

To avoid building unrealistic paths, transit travel times derived from the skim trees were inflated (or weighted) by various factors, and penalties were specified as parameters in the tree-building process. Therefore, they do not represent estimates of true zone-to-zone travel times. Obtaining both unweighted travel times and logical paths necessitated a two-step process. First, the minimum paths were built using the specified parameters. The paths were then used to compute zone-to-zone travel times by summing link travel times and wait times (assumed at one-half of the headway between vehicles) disregarding any penalties and weighting factors.

Socioeconomic Data. The main source of socioeconomic data was the 1970 U.S. Census of Population and Housing.[5] Population figures stratified by race, age, and income levels, are available at the census tract level. Specifically, the following information is extracted for relevant census tracts:

- Total population
- Ethnic minority (nonwhite) population
- Number of people over 65 years of age
- Number of families below poverty level*

The four groups are referred to in the following discussions as the general, minority, elderly, and low-income populations, respectively. To aggregate data on the four groups to the zone level, an MTC table showing the correspondence between the census tracts and the 440-zones was used. Since the networks are for the years 1971 and 1976, socioeconomic data were projected to these two years. For population forecasts, the joint Association of Bay Area Governments (ABAG) and MTC Series 2 projections[6] were used. The Series 2 projections estimate population in 1970, 1980, 1990, and 2000 for three growth alternatives.

For this study, the GROSOUTH alternative was selected. This alternative assumes that most of the region's growth occurs in the southern counties of the nine-county Bay Area Planning Region. The southern counties include the BART impact area so that GROSOUTH is more interesting than the other two alternatives, which allocate limited growth to the southern counties.

Since the ABAG/MTC projections were made at the 290-planning-zone level, they were expanded to the 440-traffic-zone level by assuming that all traffic zones in a given planning zone have the same population growth rate. The 1971 and 1976 populations for zones within the study area were then computed from the ABAG/MTC projections using linear interpolation between the 1970 and 1980 population estimates.

It was assumed that the proportions of the minority population, elderly people, and families below poverty level in individual zones for 1971 and 1976 are the same as given in the 1970 census.

Comparisons of "Before" and "After" Networks

To investigate changes in transit accessibility, the 1971 transit network is compared with the 1976 transit network in terms of zone-to-zone travel times and transit fares. Fares and times may vary depending on the type of activity

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*Families are classified as being above or below the poverty level using the poverty index adopted by a Federal Interagency Committee in 1969. This index provides a range of income cutoffs or "poverty thresholds" adjusted to take into account such factors as family size, sex and age of the family head, the number of children, and farm or nonfarm residence. These income cutoffs are updated each year to reflect the changes in the Consumer Price Index.

considered (or the time of day such activities take place), and population groups vary depending on the activity in question. Accessibility to three types of locations are considered.

- Accessibility to Employment Locations. Peak period travel times and transit fares are used to measure the employment accessibility provided by the different networks. The population groups considered are the general population, the minority population, and the low-income population.

- Accessibility to Shopping Locations. Off-peak travel times and transit fares are appropriate. The population groups considered are the general population and the minority population.

- Accessibility to Medical Locations. Emergency cases aside, it is assumed that most people travel to health care facilities during off-peak hours, and accessibility in the off-peak period is studied. Since the general population is likely to travel to private physicians, its accessibility is not studied, but the minority population, the low-income population, and elderly people are considered.

Highway and Transit Network Comparisons

The objective of the comparisons of the 1976 highway and transit networks is to assess whether BART has significantly increased or decreased the competitiveness of transit relative to the automobile. The analyses concentrate on peak period employment accessibility. As in the "before" and "after" comparisons, the employment accessibility of both the general population and the minority population are studied. The low-income segment is not included in this analysis because automobile availability is much lower for this population group. Furthermore, travel cost comparisons are not conducted, because automobile costs are not available.

Effect of Automobile Availability

The purpose of this analysis is to study the effect of automobile availability on the zone-to-zone transit accessibility of various populations. Since the transit travel time between two zones is calculated for the shortest time path, an automobile access link to a transit station would be selected in the network path-building process if the resulting path were faster than one using walking and/or transit access links to the station. That is to say, if it is faster to use an automobile to travel to a BART station than to walk to a feeder bus stop and ride the bus to the same BART station, the zone-to-zone travel time will reflect the use of an automobile as an access mode. As a consequence, this zone-to-zone travel time underestimates travel time for transit users who do not have an automobile available.

The method used in this analysis is to prohibit a transfer between the automobile and the transit modes in determining one set of shortest time paths. The effect of automobile availability on transit accessibility is examined by comparing the travel times from these paths with the corresponding times from paths allowing automobile access.

III. RESULTS AND DISCUSSIONS: "BEFORE" AND "AFTER" COMPARISONS

In this chapter, the 1971 and 1976 transit networks are compared. Conclusions are drawn on BART's impacts on access to various activities for different groups of potential transit users.

BART's Impact on Employment Access as Measured by Peak Period Travel Time

In general, peak period travel time by transit decreases when BART is included in the transit system. These decreases vary with employment location and with the particular population group under consideration.

Figures 3 and 4 are maps showing changes in accessibility to the San Francisco and Oakland CBDs, respectively. In terms of one-to-one zone accessibility, peak period travel times to the CBDs of San Francisco and Oakland are not very different between the two networks for most zones. This is what one would expect since, in 1971, most zones in the study area were well served by AC Transit and MUNI buses to the two CBDs.

Significant decreases in travel times occur for zones located at the ends of the Fremont, Concord, and Daly City Lines as well as those in the Danville and Alamo area. Before BART, these areas were served by other transit systems (e.g., Greyhound) that did not have frequent service. With the introduction of BART and its feeder-bus services to the Antioch, Danville, Livermore, and Pacifica areas, travel times from these areas to the San Francisco and Oakland CBDs decreased significantly.

Figure 5 is a map of transit travel time changes for 1971 and 1976 between zones in the study area and the zone containing the General Motors Plant in Fremont. The change in travel times to the General Motors Plant is quite large for all zones in the study area. Since Fremont was not well connected with other zones in the 1971 (pre-BART) transit network, BART service to Fremont makes the area far more accessible in 1976.

In interpreting all three figures, a small travel time change for a particular zone can be explained by one of two sets of circumstances: (1) the zone was already well served by transit in 1971, or (2) it was poorly served in 1971 and will still be poorly served in 1976. In the first case, no change in travel time is apparent even though BART may now serve the zone well.

The many-to-one zone accessibility analyses support the above conclusions about BART's impacts on accessibility for the total population. In addition, the many-to-one analyses allow a discussion of BART's differential impact on various population segments. Graph 1 in Appendix B reveals travel time changes for the general population as relatively small, except for outlying areas far from the San Francisco CBD. It also shows that accessibility changes for the minority population are relatively small even in the outlying areas. This largely results from the fact that a large proportion of minority

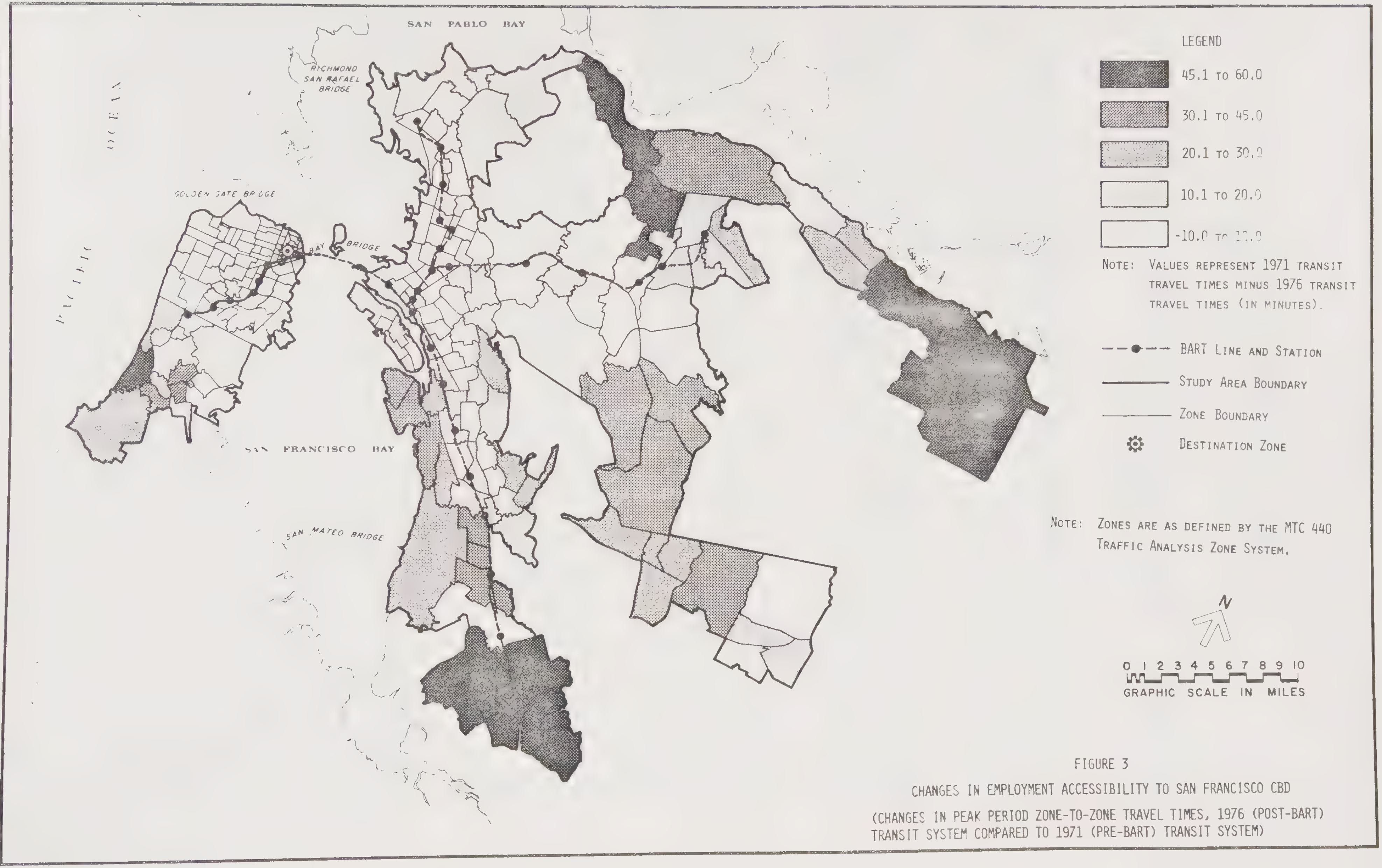

FIGURE 3

CHANGES IN EMPLOYMENT ACCESSIBILITY TO SAN FRANCISCO CBD

(CHANGES IN PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM COMPARED TO 1971 (PRE-BART) TRANSIT SYSTEM)

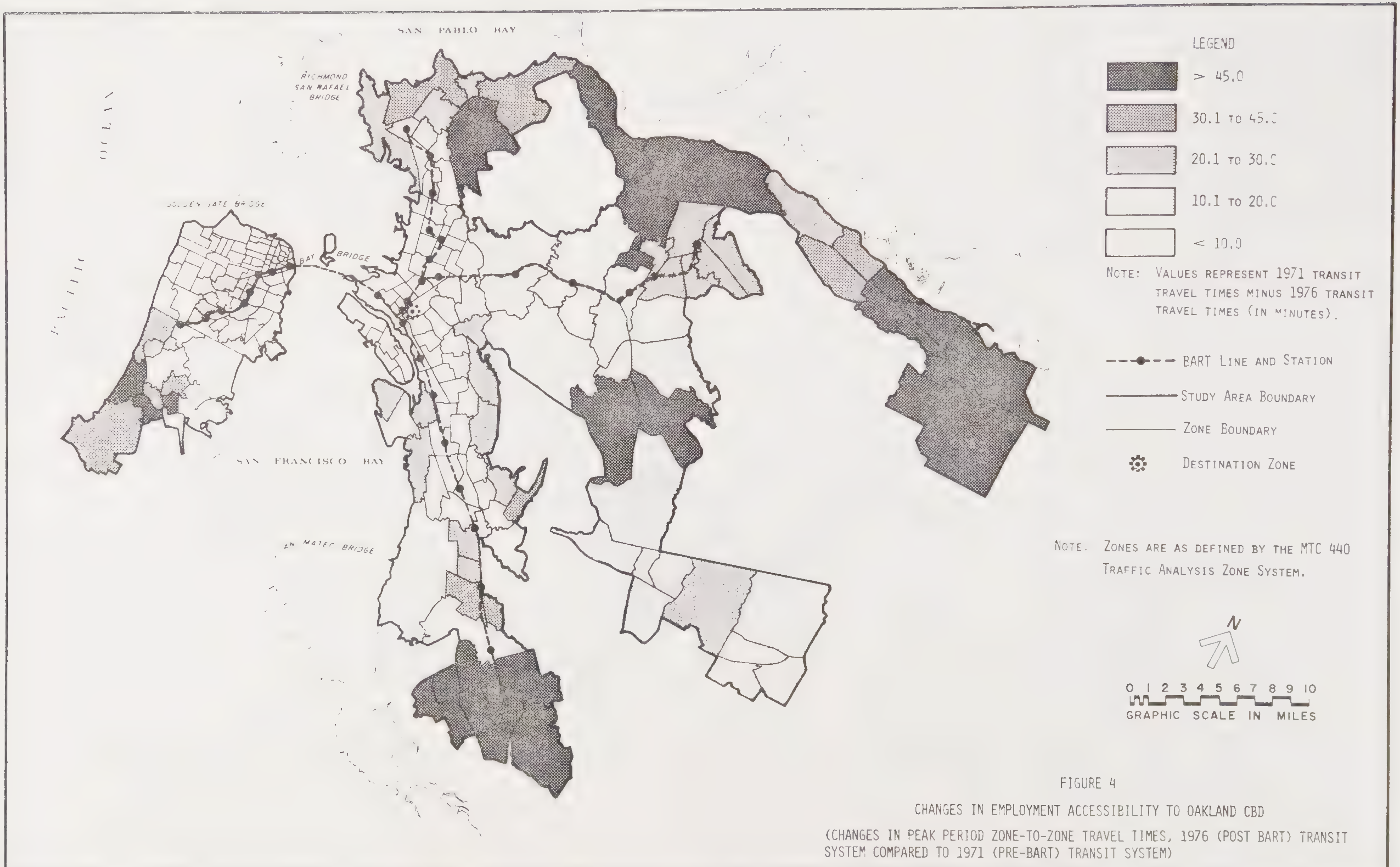

FIGURE 4

CHANGES IN EMPLOYMENT ACCESSIBILITY TO OAKLAND CBD

(CHANGES IN PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST BART) TRANSIT SYSTEM COMPARED TO 1971 (PRE-BART) TRANSIT SYSTEM)

FIGURE 5

CHANGES IN EMPLOYMENT ACCESSIBILITY TO FREMONT GENERAL MOTORS PLANT

(CHANGES IN PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM COMPARED TO 1971 (PRE-BART) TRANSIT SYSTEM)

people live either quite close to the San Francisco CBD, or in areas already well served by MUNI and AC Transit. Therefore, the addition of BART service does not improve their employment accessibility to the same extent as it does for the general population, where accessibility is measured in terms of travel time. If accessibility were measured in terms of reliability, security, or safety, there may be a greater relative improvement for the minority population.

To a lesser degree, the same conclusion can be drawn when comparing low-income people with the general population. BART service improves employment accessibility for low-income people, but not to the extent that it improves accessibility for the general population.

In general, BART provides greater employment accessibility to the Oakland CBD. As shown in Graph 2 in Appendix B, the improvement for minority people is, again, slightly less. Indeed, for minority and low-income groups located within 25 minutes of the Oakland CBD, transit travel time actually increases. Rerouting and frequency reductions of AC Transit services in certain areas may have caused these slight increases in travel times.

Employment access to the General Motors Plant in Fremont (Graph 3 in Appendix B), measured by percentage of population reached within a specific travel time, improved for all three population groups. In fact, the improvement for minority and low-income people was slightly greater than for the general population. The reason for this is that most minority and low-income groups live farther away from Fremont (for example, most of them live in Richmond, Oakland, and San Francisco).

The average travel times presented in Table 1 lend support to the above conclusions. For access to the San Francisco and Oakland CBDs, the average travel time for the minority population is lower than for the general population indicating that they live closer to the CBDs than the general population. The differences between the average times associated with the 1971 and 1976 networks are somewhat smaller for the minority population than for the general and low-income populations. This supports the conclusion that for the three employment destinations studied, BART improves employment accessibility of minority people relatively less than it improves employment accessibility for the general and low-income populations.

In comparing transit networks, two average travel times are computed for the 1976 transit network. One value represents the average travel time between the destination considered and the zones that were connected in the 1971 network.* The other value includes all zones that are connected in the 1976 network. The incremental changes in the two 1976 times for the San Francisco and Oakland CBDs are somewhat smaller for the minority population than for the general and low-income populations.

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*A maximum weighted travel time of 255 minutes was used as the upper limit in building skim trees for the transit networks. Only zones that are less than 256 minutes from the destination are considered "connected."

Table 1

SUMMARY OF AVERAGE PEAK PERIOD TRAVEL TIMES
(Minutes)

Comparison: 1971 Transit Network vs 1976 Transit Network
Activity: Employment

		General Population			Minority Population.			Low-Income Population		
Destination Zone	Transit Network	Travel Time	Reduction	Percent Reduction	Travel Time	Reduction	Percent Reduction	Travel Time	Reduction	Percent Reduction
San Francisco CBD	1971	54.2	--	--%	40.9	--	--%	48.1	--	--%
	1976[a]	43.0	11.2	20.7	34.8	6.1	14.9	39.5	8.6	17.9
	1976[b]	44.6	9.6	17.7	35.1	5.8	14.2	41.3	6.8	14.1
Oakland CBD	1971	59.5	--	--	48.8	--	--	54.0	--	--
	1976[a]	42.0	17.5	29.4	37.1	11.7	24.0	39.4	14.6	27.0
	1976[b]	43.1	16.4	27.6	37.3	11.5	23.6	40.9	13.1	24.3
Fremont General Motors Plant	1971	131.9	--	--	134.1	--	--	132.0	--	--
	1976[a]	70.0	61.9	46.9	70.4	63.7	47.5	68.7	63.3	48.0
	1976[b]	73.2	58.7	44.5	71.8	62.3	46.6	72.5	59.5	45.1

a. Includes only zones that were connected to the destination zone in 1971.
b. Includes all zones.

Source: PMM&Co. analysis.

BART's Impact on Shopping Access as Measured by Off-Peak Travel Time

In general, the results of this analysis--as presented in Graphs 4, 5, and 6 in Appendix B and Table 2--are similar to those of the preceding section. For shopping access to the San Francisco CBD (Graph 4 in Appendix B), BART reduces off-peak travel times for the general population. This may be due to BART's better transbay service frequency in the off-peak hours, especially for central Contra Costa County and southern Alameda County residents. Travel times for the minority population are reduced by a smaller amount because most minority people live in San Francisco, Oakland, and Richmond, where residents were previously served by either MUNI or AC Transit. Both bus lines offered better off-peak transbay bus services than that provided to central Contra Costa County.

Similar conclusions can be reached regarding shopping access to the Oakland CBD (Graph 5 in Appendix B), although the difference in accessibility changes between the general population and the minority population is not as great.

The third shopping access zone, the Bay Fair Shopping Center in San Leandro, is located next to a BART station. In the 1971 network, this area was well connected only with zones in Oakland and Hayward. Hence, a significant reduction in travel time occurs when comparing the 1971 and 1976 networks (Graph 6 in Appendix B). Accessibility changes between the two population groups considered do not differ significantly.

BART's Impacts on Medical and Health Care Access as Measured by Off-Peak Travel Time

The results of this analysis are presented in Graphs 7, 8, and 9 in Appendix B and in Table 3. At first glance, one might conclude that BART reduced off-peak travel times to the three medical facilities for low-income people, elderly people, and minority people, in that order.

A closer examination of Graphs 7 to 9 reveals a somewhat different story. Access to the Kaiser Hospital in Oakland does not improve significantly for most of the population. The big decrease in travel times potentially occurs for people who live in zones over 50 minutes from the hospital. It is likely that these people would go to another Kaiser hospital or clinic which is closer to their origin (for example, in San Francisco, Richmond, or Walnut Creek), with the resulting implication that BART has not really improved access to the Oakland Kaiser Hospital. (Note that this does not consider services that might only be provided by the Oakland Kaiser Hospital. However, people requiring such services are likely to be seriously ill and would probably not use the transit system.)

Users of the University of California Medical Center in San Francisco and San Francisco General Hospital are mostly San Francisco residents, although the University of California Medical Center serves patients from other counties. The accessibility changes shown on Graphs 8 and 9 indicate that the accessibility of San Francisco residents to these two facilities following the introduction of BART remains virtually unchanged.

Table 2

SUMMARY OF AVERAGE OFF-PEAK TRAVEL TIMES
(Minutes)

Comparison: 1971 Transit Network vs 1976 Transit Network
Activity: Shopping

		General Population			Minority Population		
Destination Zone	Transit Network	Travel Time	Reduction	Percent Reduction	Travel Time	Reduction	Percent Reduction
San Francisco CBD	1971	61.8	--	--%	44.8	--	--%
	1976[a]	45.9	15.9	25.7	37.3	7.5	16.7
	1976[b]	46.3	15.5	25.1	37.3	7.5	16.7
Oakland CBD	1971	62.6	--	--	49.9	--	--
	1976[a]	44.6	18.0	28.8	39.0	10.9	21.8
	1976[b]	45.0	17.6	28.1	39.1	10.8	21.6
Bay Fair Shopping Center	1971	89.6	--	--	82.8	--	--
	1976[a]	61.6	28.0	31.3	59.8	23.0	27.8
	1976[b]	62.5	27.1	30.2	59.9	22.9	27.7

A. Includes only zones that were connected to the destination in 1971.
b. Includes all zones.

Source: PMM&Co. analysis.

Table 3

SUMMARY OF AVERAGE OFF-PEAK TRAVEL TIMES
(Minutes)

Comparison: 1971 Transit Network vs 1976 Transit Network
Activity: Medical and Health Care

		Minority Population			Low-Income Population			Elderly Population		
Destination Zone	Transit Network	Travel Time	Reduction	Percent Reduction	Travel Time	Reduction	Percent Reduction	Travel Time	Reduction	Percent Reduction
Oakland Kaiser	1971	51.2	--	--%	59.6	--	--%	56.1	--	--%
Hospital	1976[a]	42.4	8.8	17.2	46.1	13.5	22.7	45.2	10.9	19.4
	1976[b]	42.5	8.7	17.0	46.4	13.2	22.1	45.5	10.6	18.9
University of	1971	61.4	--	--	71.2	--	--	64.2	--	--
California	1976[a]	54.4	7.0	11.4	60.6	10.6	14.9	55.0	9.2	14.3
Medical Center	1976[b]	54.5	6.9	11.2	61.2	10.0	14.0	55.6	8.6	13.4
San Francisco	1971	58.8	--	--	67.6	--	--	63.6	--	--
General Hospital	1976[a]	49.7	9.1	15.5	54.4	13.2	19.5	52.1	11.5	18.1
	1976[b]	49.7	9.1	15.5	55.0	12.6	18.6	52.6	11.0	17.3

a. Includes only zones that were connected to the destination in 1971.
b. Includes all zones.

Source: PMM&Co. analysis.

BART's Accessibility Impact as Measured by Transit Fare

Accessibility to the same activities and destinations discussed in the earlier sections of this chapter was also studied by comparing transit fares. The results are presented in Graphs 10 to 18 in Appendix B, Figures 6 to 8, and Tables 4 to 6.

In most cases, the 1976 transit fare is higher than the 1971 transit fare for a large percentage of the population. Peak period transit fares for employment access to the San Francisco and Oakland CBDs increased an average of 32% and 19%, respectively, for the general population; 39% and 16%, respectively, for the minority population; and 31% and 18%, respectively, for the low-income population. Similarly, average off-peak transit fares to the San Francisco and Oakland CBDs and the Bay Fair Shopping Center increased by 21%, 12%, and 16%, respectively, for the general population and by 28%, 12%, and 26%, respectively, for the minority population. Average off-peak transit fares to the three selected medical centers increased by about 11% for the minority population and 8% for the low-income and elderly populations. These transit fare increases are quite significant.

Although one might attribute these transit fare increases to inflation between 1971 and 1976, MUNI's 25-cent fare has not changed and AC Transit has increased its fare by five cents on only a few selected routes. Since these are the two major bus companies in the study area, it is evident that the increase in average transit fares between 1971 and 1976 results from travelers using travel paths involving BART rather than using MUNI or AC Transit for the entire trip. Since BART fares are always equal to or higher than the corresponding fares charged by MUNI or AC Transit, 1976 fares are generally higher than the corresponding 1971 fares.

The methodological limitations of this fare analysis should be recognized. Travel paths between each pair of zones for which transit fares are computed are based on the professional judgment of the analyst; they are not necessarily based on minimum travel time paths.

The 1976 transit fare matrices are coded so that "whenever reasonable, a travel path involving the use of BART was selected--even if an alternative non-BART path was available."[4] Thus, in coding the 1976 transit fare matrices, travel paths including the relatively more expensive BART service may have been chosen more than can be justified by minimum travel times. To compare the travel paths assumed for the fare analysis to minimum travel time paths was beyond the resources of this project. Also, some travelers (particularly low-income travelers) might select a travel path with a slightly longer travel time but a smaller transit fare. In this case, the transit fare estimates in Tables 4, 5, and 6 would be the upper bound of the increases.

An exception to the fare increase pattern occurs for zones served by either Greyhound or Peerless Stages in the 1971 transit system. In these cases, the 1976 fares are less than the 1971 fares, since the cost of using either Greyhound or Peerless Stages in 1971 is higher than the cost of using BART in

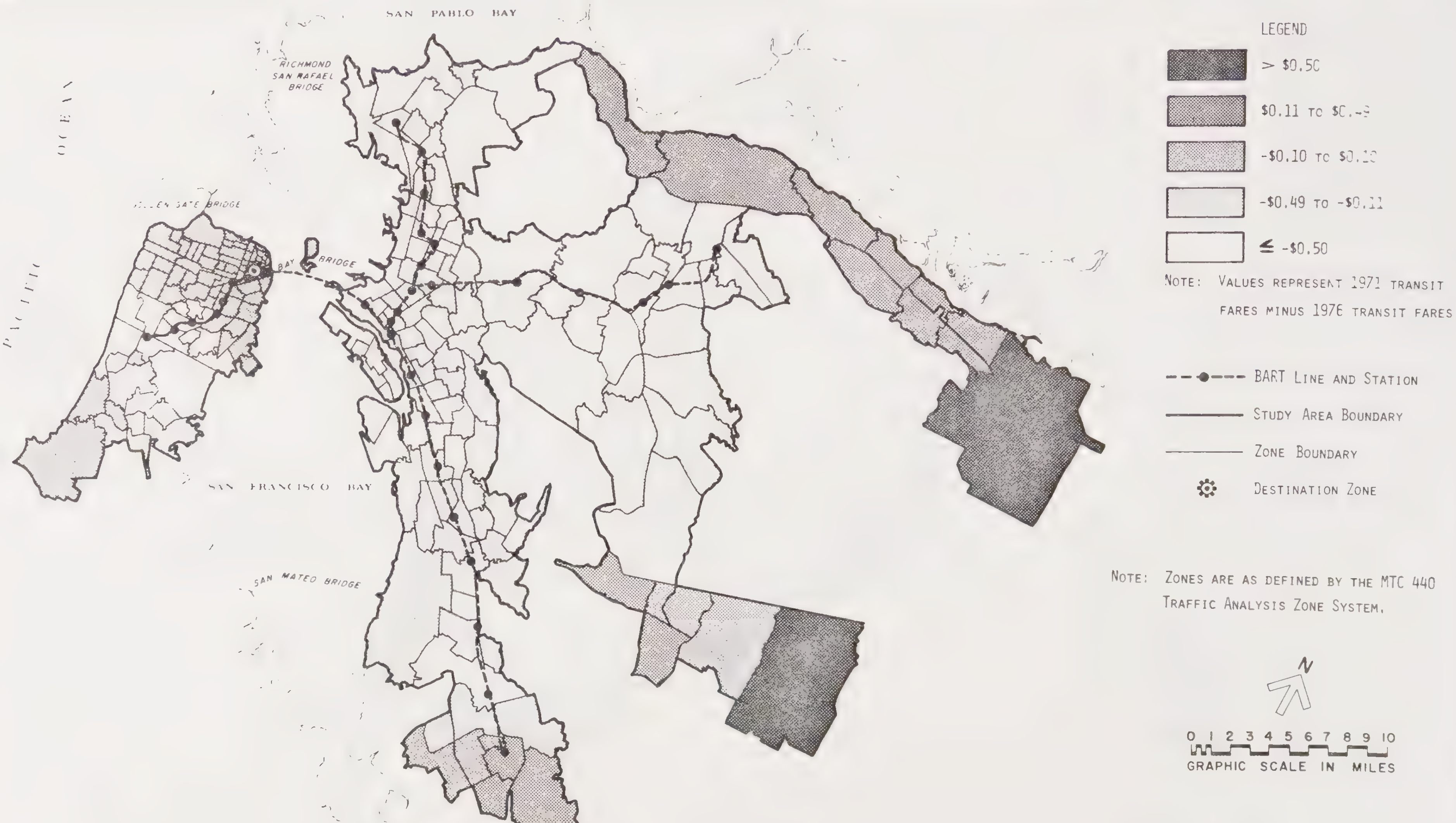

FIGURE 6

CHANGES IN EMPLOYMENT ACCESSIBILITY TO SAN FRANCISCO CBD

(CHANGES IN PEAK PERIOD ZONE-TO-ZONE TRANSIT FARES, 1976 (POST-BART) TRANSIT SYSTEM COMPARED TO 1971 (PRE-BART) TRANSIT SYSTEM)

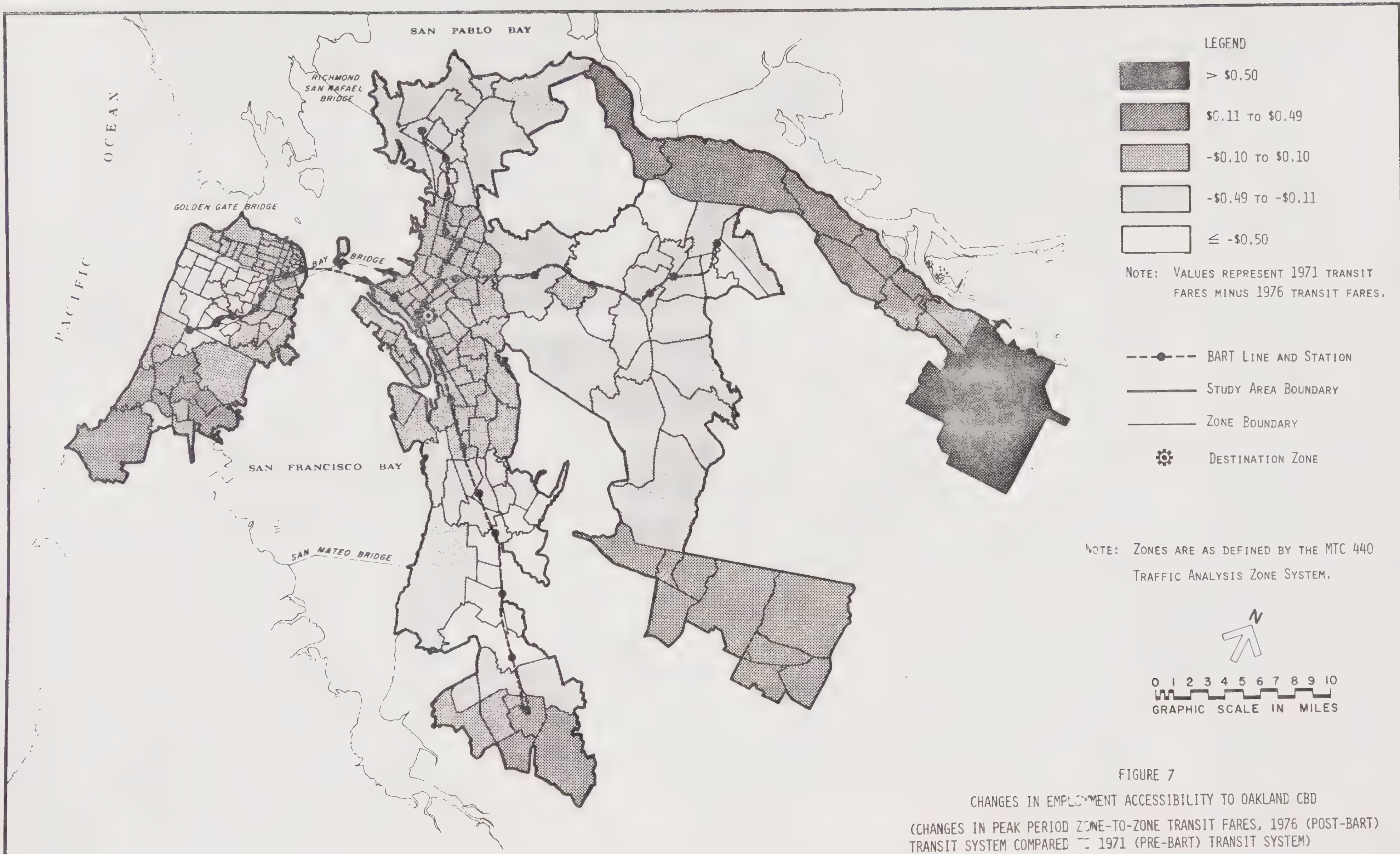

FIGURE 7

CHANGES IN EMPLOYMENT ACCESSIBILITY TO OAKLAND CBD

(CHANGES IN PEAK PERIOD ZONE-TO-ZONE TRANSIT FARES, 1976 (POST-BART) TRANSIT SYSTEM COMPARED TO 1971 (PRE-BART) TRANSIT SYSTEM)

FIGURE 8

CHANGES IN EMPLOYMENT ACCESSIBILITY TO FREMONT GENERAL MOTORS PLANT

(CHANGES IN PEAK PERIOD ZONE-TO-ZONE TRANSIT FARES, 1976 (POST-BART) TRANSIT SYSTEM COMPARED TO 1971 (PRE-BART) TRANSIT SYSTEM)

Table 4

SUMMARY OF AVERAGE PEAK PERIOD TRANSIT FARES
(Dollars)

Comparison: 1971 Transit Network vs 1976 Transit Network
Activity: Employment

		General Population			Minority Population			Low-Income Population		
Destination Zone	Transit Network	Transit Fare	Change	Percent Change	Transit Fare	Change	Percent Change	Transit Fare	Change	Percent Change
San Francisco CBD	1971	$0.65	$ --	--%	$0.46	$ --	--%	$0.59	$ --	--%
	1976	0.86	+0.21	+32.3	0.64	+0.18	+39.1	0.77	+0.18	+30.5
Oakland CBD	1971	0.69	--	--	0.55	--	--	0.63	--	--
	1976	0.82	+0.13	+18.8	0.64	+0.09	+16.4	0.74	+0.11	+17.5
Fremont General	1971	1.64	--	--	1.57	--	--	1.63	--	--
Motors Plant	1976	1.30	-0.34	-20.7	1.34	-0.23	-14.6	1.32	-0.31	-19.0

Source: PMM&Co. analysis.

Table 5

SUMMARY OF AVERAGE OFF-PEAK TRANSIT FARES
(Dollars)

Comparison: 1971 Transit Network vs 1976 Transit Network
Activity: Shopping

		General Population			Minority Population		
Destination Zone	Transit Network	Transit Fare	Change	Percent Change	Transit Fare	Change	Percent Change
San Francisco CBD	1971	$0.72	$ --	--%	$0.50	$ --	--%
	1976	0.87	+0.15	+20.8	0.64	+0.14	+28.0
Oakland CBD	1971	0.73	--	--	0.57	--	--
	1976	0.82	+0.09	+12.3	0.64	+0.07	+12.3
Bay Fair Shopping Center	1971	0.83	--	--	0.70	--	--
	1976	0.96	+0.13	+15.7	0.88	+0.18	+25.7

Source: PMM&Co. analysis.

Table 6

SUMMARY OF AVERAGE OFF-PEAK TRANSIT FARES
(Dollars)

Comparison: 1971 Transit Network vs 1976 Transit Network
Activity: Medical and Health Care

		Minority Population			Low-Income Population			Elderly Population		
Destination Zone	Transit Network	Transit Fare	Change	Percent Change	Transit Fare	Change	Percent Change	Transit Fare	Change	Percent Change
Cakland Kaiser	1971	$0.57	$ --	--%	$0.67	$ --	--%	$0.67	$ --	--%
Hospital	1976	0.64	+0.07	+12.3	0.74	+0.07	+10.4	0.73	+0.06	+9.0
University of	1971	0.64	--	--	0.80	--	--	0.72	--	--
California	1976	0.71	+0.07	+10.9	0.85	+0.05	+ 6.3	0.77	+0.05	+6.9
Medical Center										
San Francisco	1971	0.64	--	--	0.80	--	--	0.72	--	--
General Hospital	1976	0.71	+0.07	+10.9	0.86	+0.06	+ 7.5	0.78	+0.06	+8.3

Source: PMM&Co. analysis.

1976. This is reflected in the fares for employment access to the General Motors Plant (Table 4 and Graph 12). For the other employment destinations considered, the same situation applies as shown in Graphs 10 to 18. The zones furthest from the destinations, which were served either by Greyhound or Peerless buses, had higher fares in 1971 than in 1976.

The results do not show any significant differential impacts on various population groups. This may be due to the fact that fare matrices were developed at the district level with each district covering a large number of zones which does not allow differentiation between population groups. Although some refinements were accomplished at the zone level when developing the fare matrices, the resulting differences are not significant.

Summary of Results

The results of the "before" and "after" comparisons of transit accessibility indicate that BART:

- Provides improved access by decreasing travel times to selected employment and shopping facilities adjacent to the BART lines.

- Provides reduced travel times to selected medical facilities located a moderate distance from the BART lines for those residents located more than 50 minutes from the facilities. But it does not significantly affect accessibility to medical facilities for residents residing less than 50 minutes from the facilities. People living closer to the facilities probably make up the great majority of those who might use transit to access the facilities.

- Produces differential impacts on various segments of the population. The minority population benefits the least in travel time savings, low-income and elderly people benefit more, general population benefits most.

In general, transit fares increased because of BART, except for those travelers who live in areas that were previously served by either Greyhound or Peerless Stages and are now served by BART.

IV. RESULTS AND DISCUSSIONS: TRANSIT VS. AUTOMOBILE

This chapter focuses on results obtained by comparing the 1976 transit network and the 1976 highway network. In addition, the effect of automobile availability on transit users is examined.

Comparison of Employment Access Provided by the 1976 Highway and Transit Networks

Peak period skim trees and travel times were developed from zones in the study area to the three employment destinations studied in Chapter III. The highway network was developed without the inclusion of terminal times. For work journeys to the San Francisco CBD, a transit user alights at a station or a stop rather close to his destination. On the other hand, an automobile user must find a parking space. This is difficult in the CBD and may be far from his destination. To make travel times for the two networks comparable, a total terminal time of five minutes was added to the residential and workplace ends of the highway network times for work trips to the San Francisco CBD.

Figure 9 shows the difference in highway and transit travel time from each zone in the study area to the San Francisco CBD. Graph 19 in Appendix B plots cumulative percentages of the general and minority populations reached within a certain travel time from the San Francisco CBD. Two observations can be made based on these graphs: (1) travel times on the highway network and the transit network differ insignificantly for both population groups studied, but (2) travel times differ noticeably for the general population when the zones are more than 70 minutes from the San Francisco CBD. These findings can be attributed to the effects of peak period congestion, particularly on the San Francisco-Oakland Bay Bridge. Traffic congestion increases highway travel times to about the same level as transit times in the central areas. However, for outlying zones to which more of the highway journey is made under lighter traffic conditions, the time advantage of the automobile over transit increases. This conclusion is evidenced in the map presented in Figure 9 where the largest savings in travel time due to the use of highway occur in zones in the Antioch area and the Livermore Valley area; and, to a lesser degree, in the northern San Mateo County zones and the San Pablo-Pinole area. As discussed in Chapter III, most of the minority population resides less than an hour away from the San Francisco CBD. For this reason, the accessibility of the minority population to the San Francisco CBD is not improved as much as that of the general population.

In the time frame of this analysis, parking is less of a problem in the Oakland CBD than in the San Francisco CBD. For the analysis of employment access to the Oakland CBD, a total highway terminal time of two minutes is assumed for both the workplace and residential ends of the trip. The results displayed in Graph 20 of Appendix B and Figure 10 show differences in travel time between the 1976 highway and transit networks.

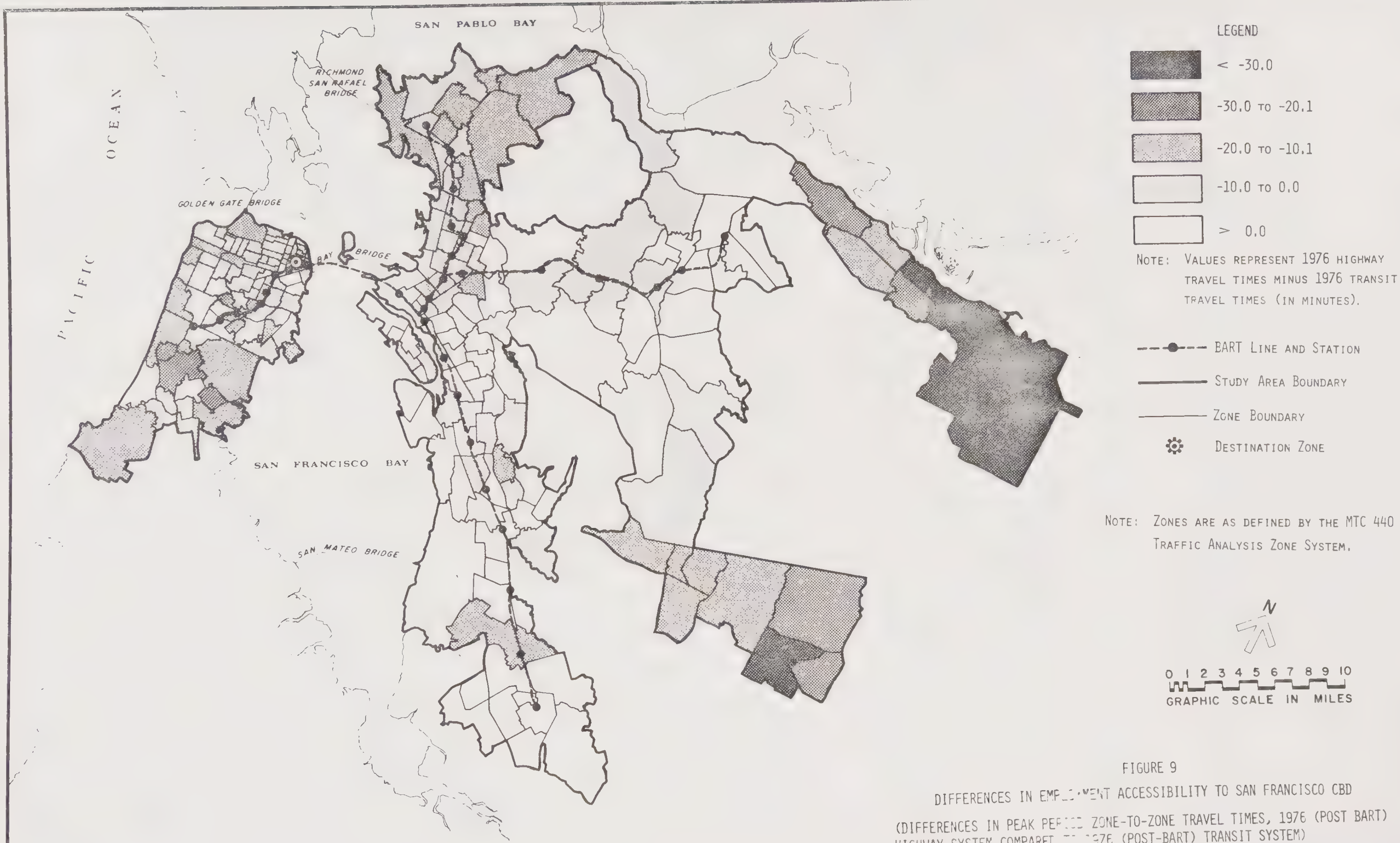

FIGURE 9

DIFFERENCES IN EMPLOYMENT ACCESSIBILITY TO SAN FRANCISCO CBD

(DIFFERENCES IN PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST BART) HIGHWAY SYSTEM COMPARED TO 1976 (POST-BART) TRANSIT SYSTEM)

FIGURE 1[illegible]

DIFFERENCES IN EMPLOYMENT ACCESSIBILITY TO OAKLAND CBD

(DIFFERENCES IN PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) HIGHWAY SYSTEM COMPARED TO 1976 (POST-BART) TRANSIT SYSTEM)

If travel time is the only factor of concern, it is always better to use highway; because some of the travelers are "reverse commuting" (traveling against the direction of the principal traffic flow). For reverse commuters, highway travel times are especially low (relative to transit) because (1) highway facilities are not as congested in the reverse direction, and (2) transit headways may be longer. However, BART has improved the competitiveness of transit (relative to the 1971 network) to highway as indicated on Graph 20 in Appendix B; even though highway travel times are still lower than transit travel times in 1976. The travel time differences between the 1976 highway and transit networks are less than 50% of the travel time differences between the 1976 highway network and the 1971 transit network. The graphs also show that there are no significant differential impacts for the two populations studied.

Results of the study of employment access to the General Motors Plant in Fremont are presented in Graph 21 in Appendix B and Figure 11. The differences in travel time between the highway and transit networks are quite significant and are similar for both population groups.

Table 7 presents the average peak period travel times for the two networks and the case studies considered. These results lend further support to the conclusions reached in the preceding paragraphs.

The Effect of Automobile Availability on Transit Travel Times

This section discusses the effects of automobile availability on transit accessibility. In the 1971 transit network, a traveler has only two choices for reaching a transit (bus) stop: by car or on foot. An inspection of the network description reveals that if the automobile access links are eliminated from the few skim trees that have them, the resulting travel times using the walking links would exceed the maximum travel time specified. Thus, the zones connected to the transit network through automobile access links would be disconnected from the network if the automobile links were replaced by walking links.

In the 1976 transit network, more access links are available because it incorporates BART stations. If the shortest time path involves the use of BART, a traveler can walk to a BART station; drive or be driven to a BART station; or walk to a transit (bus) stop and then ride to a BART station. The elimination of automobile access links in this case does not necessarily imply the zones have to be disconnected. For this reason, the 1976 transit network forms a more interesting basis for the automobile availability comparisons discussed below.

Employment Access. Peak period travel times by transit were obtained between zones in the study area and employment destinations in the CBDs of San Francisco and Oakland. As shown in Graphs 22 and 23 in Appendix B, the elimination of automobile access links decreases the employment accessibility of the general population. However, it does not have a significant effect on the employment accessibility of the minority population. This suggests that

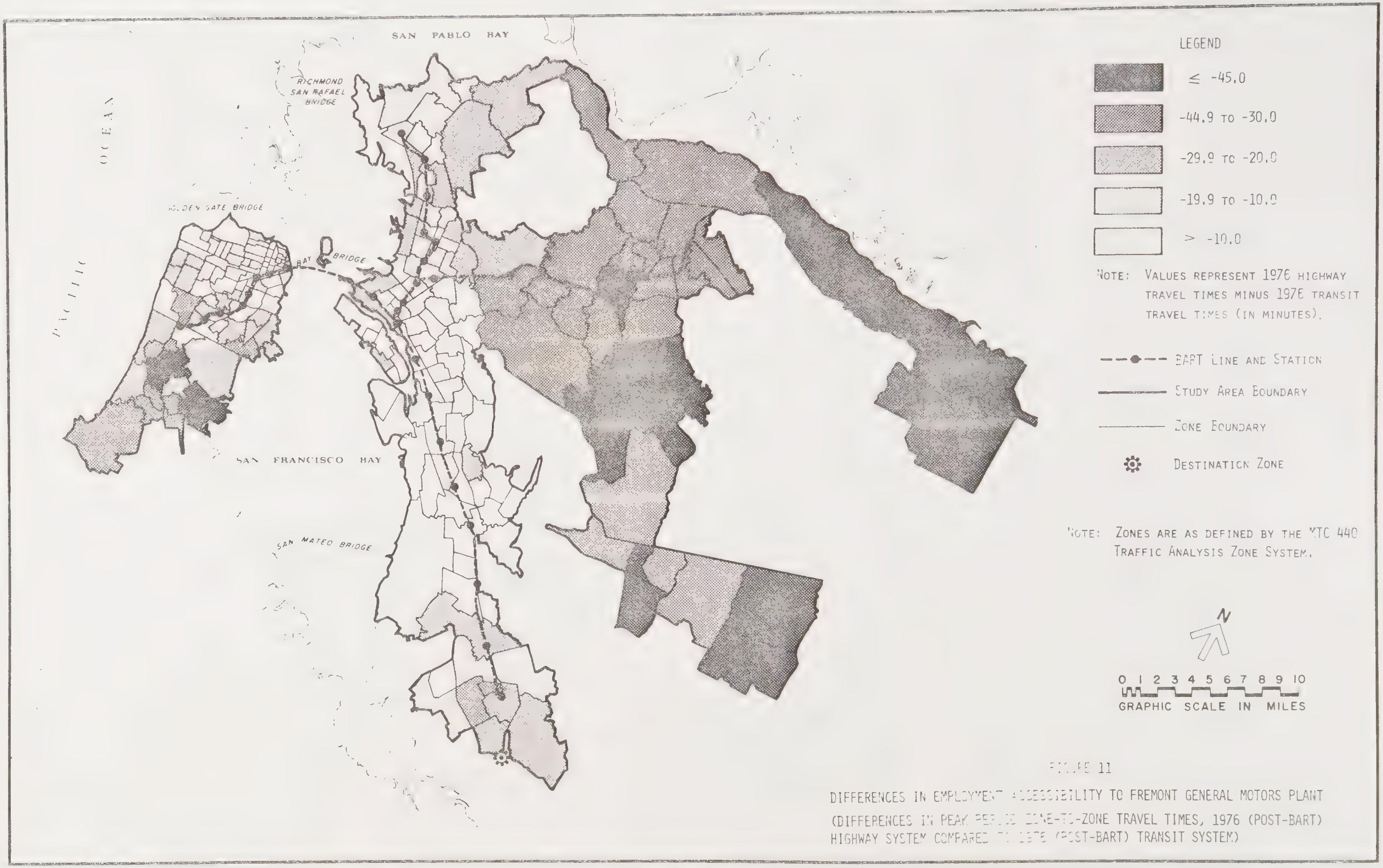

FIGURE 11

DIFFERENCES IN EMPLOYMENT ACCESSIBILITY TO FREMONT GENERAL MOTORS PLANT

(DIFFERENCES IN PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) HIGHWAY SYSTEM COMPARED TO 1976 (POST-BART) TRANSIT SYSTEM)

Table 7

SUMMARY OF AVERAGE PEAK PERIOD TRAVEL TIMES
(Minutes)

Comparison: 1976 Transit Network vs 1976 Highway Network
Activity: Employment

Destination Zone	Network[a]	General Population			Minority Population		
		Transit Time	Reduction	Percent Reduction	Transit Time	Reduction	Percent Reduction
San Francisco CBD	1976T	44.6	--	--%	35.1	--	--%
	1976H	35.6	9.0	20.2	26.4	8.7	24.8
	1976H[b]	40.6	4.0	9.0	31.4	3.7	10.5
Oakland CBD	1976T	43.1	--	--	37.2	--	--
	1976H	28.7	14.4	33.4	22.5	14.7	39.5
	1976H[c]	30.7	12.4	28.8	24.5	12.7	34.1
Fremont General	1976T	73.2	--	--	71.8	--	--
Motors Plant	1976H	44.8	28.4	38.8	49.3	22.5	31.3

a. T = transit network; H = highway network.
b. Includes 5-minute terminal time.
c. Includes 2-minute terminal time.

Source: PMM&Co. analysis

a large proportion of minority residents live within walking distance of the transit system. Interestingly, low-income people, who can least afford to have an automobile, have their employment accessibility reduced if automobile access links are replaced by walking links in the transit network.

Since one would expect employees of an automobile manufacturer to have easier access to an automobile, accessibility to the Fremont General Motors Plant zone was not analyzed with regard to automobile availability.

Shopping Access. Graphs 24 to 26 in Appendix B show results of the analysis of shopping access (measured by off-peak travel times) to the San Francisco and Oakland CBDs and the Bay Fair Shopping Center. The conclusions are similar to those developed in the preceding section.

Medical Access. Once again, the minority population is not significantly affected as evidenced in Graphs 27 to 29 in Appendix B. Although a comparison of off-peak travel times indicates that automobile availability affects the medical accessibility of the low-income and elderly populations, a closer inspection of the plots show that the same arguments advanced in Chapter III can be applied in this case. That is, the medical facilities studied are oriented towards serving local residents. The accessibility of low-income and elderly people residing within an hour's travel time of these facilities does not seem to change significantly. Therefore, the lack of an automobile does not affect the accessibility of most users to these medical facilities.

Summary of Results

Based on the previous discussions, several points are worth noting:

- Peak travel times to the San Francisco CBD on the highway and transit networks are similar because travel is in the direction of peak traffic flow and the highways are quite congested.

- Peak travel times to the Oakland CBD and the Fremont General Motors Plant tend to be smaller for highway users than for transit users because the proportion of reverse commuters increases and the highways are less congested.

- Most minority people live close enough to the transit system so that they do not need an automobile to access transit services.

- The lack of an automobile significantly decreases employment accessibility for transit users in the general population and the low-income population.

- Medical accessibility of the minority, low-income, and elderly populations is not significantly affected by automobile availability. The assertion that most medical facilities are locally oriented, with respect to providing day-to-day health care, must be proved by further investigation.

V. ASSESSMENT OF METHODOLOGY

The previous two chapters have presented findings from the exploratory network accessibility analyses. These findings must be interpreted in the context of the methodology used, which has a number of limitations. This chapter discusses some of these limitations in an attempt to evaluate the usefulness of conventional network accessibility analyses in evaluating BART's impacts.

Zones Selected for Analysis

Since the analyses consider accessibilities to only 7 of the 225 traffic zones in the study area, conclusions about BART's impacts on accessibility in the 7 zones cannot be directly generalized to the whole BART impact area. In particular, it should be noted that most of the 7 zones considered are very well served by BART. Accordingly, these accessibility analyses show BART causing greater improvements in accessibility than would be the case for most zones in the area.

An analysis to assess BART's accessibility impacts on the entire Bay Area would have to study a much larger number of zones, including areas poorly served by BART. Clearly, this would greatly increase the expense involved in building the necessary minimum travel time path trees.

In this report, a particular activity location has been described and analyzed in terms of the traffic zone containing the activity location, as if the two were identical. However, each traffic zone is represented in the network by a single centroid, and the location of the activity analyzed and the location of the centroid in the zone will rarely be the same. Therefore, errors will occur when different networks are compared. These errors could be appreciable for large zones. The problem is quite common in network analyses and can be resolved only by recoding the networks so that the zone centroids are located at the activity centers of interest.

Network Representation

Clearly, the results presented in the previous chapters are meaningful only insofar as the networks realistically represent the transportation system and travelers' use of it. Conventional networks, such as those utilized in this study, are crude representations of the transportation system,* which are useful in some, but not necessarily all, transportation system analysis applications. Therefore, network limitations must be understood in the

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*This does not imply that the networks coded by the TSTB Project are less accurate representations of reality than the networks used in other transportation planning contexts. Indeed, the opposite is probably the case.

present context. The scope of this study does not allow a complete discussion of the many potential problems associated with the use of conventional networks. The following sections merely point out some of the more apparent limitations.

Conventional Network Measures. Network representations are subject to error and bias. Each link of the network is represented by a single value of travel time. This single value represents a quantity which varies among different travelers, and from day-to-day, at different times of day. This potential error could be assessed by comparison of network skim tree travel time values and travel times observed independently, using physical measurements of time. However, validation would require a large and costly program of data collection and analysis.*

It can be argued that travel time alone is an inadequate measure of travel impedance--that reliability, comfort, safety, and other measures of transportation modes contribute to the true "accessibility" of different locations. Resolving this set of issues requires augmenting the travel time value for each network link with values describing the other components of travel impedance. To date, this task has not been accomplished in a comprehensive manner, and it clearly involves a great deal of data collection and network coding. Given the other inherent sources of uncertainty in network analyses, it is highly questionable whether such effort can be justified solely for accessibility analysis purposes.

Access Links. A major source of potential error is the difficulty of coding the access links at the end of trips--traveling to and from transit services or traveling from the automobile parking space to the ultimate destination. In most networks (including those used in these analyses), access links are treated in a very simplistic way and do not cover the wide distribution of modes and travel times involved in a particular zone. This problem is compounded by the fact that zones of different sizes in different areas may have very different distributions of access travel times by different modes. It is not apparent from these analyses how serious a problem this might be. Again, a fairly large research program of data collection and analysis would be required to assess this.

In comparing highway and transit travel times, highway travel times, at least for the networks developed in the TSTB Project, do not include terminal times. This means that terminal times must be added to highway travel times obtained from the highway network to compare highway and transit travel times. For

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*A comparison of network travel times and observed travel times was conducted for a limited number of zones while developing the 1971 highway network. The network run times of selected transit lines were also compared with run times derived from time tables, which may not indicate the actual run times.[2,3]

example, for work journeys to the San Francisco CBD, an automobile user has to find a parking space and then walk to his place of work. Additionally, the parking space may not be located in the same zone as his destination, although the highway travel time is computed between the centroids of his zones of origin and destination. To overcome this problem, terminal times must be assumed for the origins and destinations under consideration and added to the travel times computed from the highway network.

Network Analysis Algorithms. The skim trees are computed through a shortest time-path algorithm, a common practice. Some of them, however, may not represent paths that people usually take (or are even aware of). Further, skim trees are very sensitive to the values of the parameters specified by the user. Therefore, it is necessary to know which values to use in order to obtain logical paths. Thus, the travel time changes obtained from network analyses may not reflect true accessibility changes. To validate the minimum time-paths, it would be necessary to trace through the shortest time paths to ensure that these are paths that people actually do or would use.* However, defining a "reasonable" path is still difficult. To ascertain the realism of a network assignment would require a major data assembly and analysis effort, which is probably not justifiable.

In some cases, the shortest time path may not be the route actually selected by travelers, because a lower cost but longer travel-time route is available. Such situations could readily arise in studying BART's accessibility impacts.**

A final problem with the transit network is that the components of total travel time (walking, waiting, and riding times) are weighted differently in computing total travel time. Thus, in a sense, the network yields "perceived" total travel times, because it imposes penalties on transfers and waiting. Since this is not a study of traveler behavior (where perceived travel times might be appropriate), one has to use only unweighted times.

Automobile Availability. The transit travel times for certain segments of the population that do not have access to an automobile may be artificially low in some cases because the network-building process assumes the availability of a car. When computing transit travel times in such cases, care must be taken to insure that transfers between automobile and transit are prohibited.

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*This procedure was applied to a limited number of paths in the development of the networks.[2,3]

**One suggestion for addressing this issue is a path selection algorithm, which selects the three or four lowest generalized impedance or "disutility" transit travel paths, rather than the single minimum travel time path. At a minimum, the disutility expression would include both the travel time and the travel cost. Such an algorithm has been developed and is currently being programmed for the Urban Mass Transportation Administration's Urban Transportation Planning System (UTPS).

Fare Matrices. As discussed in Chapter III, the structure of the fare matrices developed in the TSTB Project tends to favor BART as the transit travel mode. The resulting fares between zones served by BART and other transit services may not be representative, and the comparison of the 1971 and 1976 transit fares may not be appropriate. This potential problem could be resolved by revising the fare matrices to correspond to the minimum time paths, but it is doubtful whether this would measurably add to the usefulness of the findings.

Population and Socioeconomic Data

The data in this study classified population into simple stratifications, such as minority and low-income populations. It might be of more interest to use cross-classified data--for example, the low-income, minority population. Data on other population segments and land use activities could be acquired, including the youth population and specific minority groups; work place of residents; number and types of jobs at individual locations; and other activity destinations such as educational, recreational, and social services facilities.

A further area of concern, as always, is the lack of sophistication in the forecasts of the various population and socioeconomic data. The ABAG/MTC projections were for the year 1980 and assumed a 1980 transportation network. Due to resource constraints, the transportation networks used in the ABAG/MTC study were not compared with the networks used in this study; therefore, there may be certain inconsistencies. The method used in this study was limited to applying the same zone-specific growth factors to all population segments and socioeconomic levels within the particular zone. Even the zone-specific growth factors were simple linear interpolations of other forecasts. An improvement on these forecasts would be to operate the land use model employed in the joint ABAG/MTC study using the transportation networks developed in the TSTB Project.

Choice of Population Estimates

Comparing network accessibilities for different years raises an interesting issue. Does one use the population figures corresponding to the years in question, or does one use the same population for both years as the basis for comparison? For example, in the comparison of the 1971 and 1976 transit network accessibilities, should one use the 1971 population for both networks, the 1976 population for both networks, or the 1971 population for the 1971 network and the 1976 population for the 1976 network?

Some may suggest using the 1976 population for analysis of both the 1971 and 1976 networks. This enables one to measure the accessibility of the population in 1976 relative to the accessibility they would have experienced had there been no changes in the transit system since 1971. Others may argue that population growth in certain zones is induced by the transportation system. A comparison of the 1971 and 1976 network accessibilities using the

1976 zone populations in both cases may therefore overstate the improvement in accessibility, since a significant population in 1971 will be shown as being located in relatively inaccessible zones. Therefore, it is argued, the 1971 population should be used for both networks as the basis for comparison. However, this gives rise to a bias in the opposite direction. A third point of view is that, in a network analysis of accessibility, one is interested in what actually happened in 1971 and what will happen in 1976. Hence, one should use the 1971 population for the 1971 network and the 1976 population for the 1976 network.

A sensitivity analysis studied how the results would change if different populations were used. Graphs 30 and 31 in Appendix B show cumulative percentages of population reached within a certain travel time from the San Francisco and Oakland CBDs. The results are rather insensitive to the population used as long as it is the same for both networks. The differences in percent population reached by the two networks are about the same whether the 1971 or 1976 population is used. Both networks yielded from 0% to 4% less when compared to the difference in percent population reached for the two networks using their respective populations. This difference of less than 5% seems to indicate that it does not really matter which population is used.

However, estimated population growth from 1971 to 1976 (Table 8) shows that total population and minority population increased only about 7% and 3%, respectively. The number of families below poverty level increased about 5%. In light of these percentages, the above difference becomes significant. In other words, if one were studying two time periods with very different populations, the difference in percent population reached between the two different methods (i.e., same population for different networks and different populations for different networks) could be very large.

Table 9 shows the average travel times corresponding to each of the above cases, i.e., using the 1971 or 1976 population estimates. Employment accessibility of minority population to the San Francisco CBD is an example of the different results obtained. Using the 1971 population for both networks, the difference in average travel time is (40.9 - 34.3) = 6.6 minutes. Using the 1976 population for both networks, the difference is (41.7 - 34.8) = 6.9 minutes. Using each population for its network, the difference is (40.9 - 34.8) = 6.1 minutes.

Presentation of Results

The various techniques employed in presenting analytical results have their advantages and disadvantages. No single presentation format is fully adequate. The geographic maps show changes in accessibility but give no information on the type and numbers of people affected. The cumulative plots of the proportion of specific populations reached within specific travel impedances can effectively compare changes in accessibility for different population groups. They do not, however, show the geographic location of the zones, nor do they give information on how accessibility in a particular zone has changed. Together, the two presentations give a better description

Table 8

ESTIMATED POPULATION GROWTH FROM 1971 TO 1976

Year	Population Group		
	General (persons)	Minority (persons)	Low Income (families)
1971	2,521,000	506,000	49,000
1976	2,699,000	520,000	51,300
Percent Increase	7.1%	2.8%	4.7%

Source: PMM&Co. analysis based on ABAG/MTC projections.

Table 9

AVERAGE TRAVEL TIMES FOR SENSITIVITY ANALYSIS

Destination Zone	Transit Network	Population Year	Average Travel Times by Population Group (in minutes) General	Minority	Low Income
San Francisco CBD	1971	1971	54.2	40.9	48.1
		1976	55.6	41.7	49.5
	1976	1971	42.0	34.3	38.6
		1976	43.0	34.8	39.5
Oakland CBD	1971	1971	59.5	48.8	54.0
		1976	60.7	49.4	55.1
	1976	1971	41.5	36.7	38.8
		1976	42.0	37.1	39.4

Source: PMM&Co. analysis.

of BART's impact on accessibility. The single-value summary of network impedances is only useful in providing a general indication of the accessibility provided by a network. In summary, the three techniques explored in this study seem, together, to provide a fairly effective method of presenting accessibility changes between different networks.

APPENDIX A

REFERENCES

Appendix A

REFERENCES

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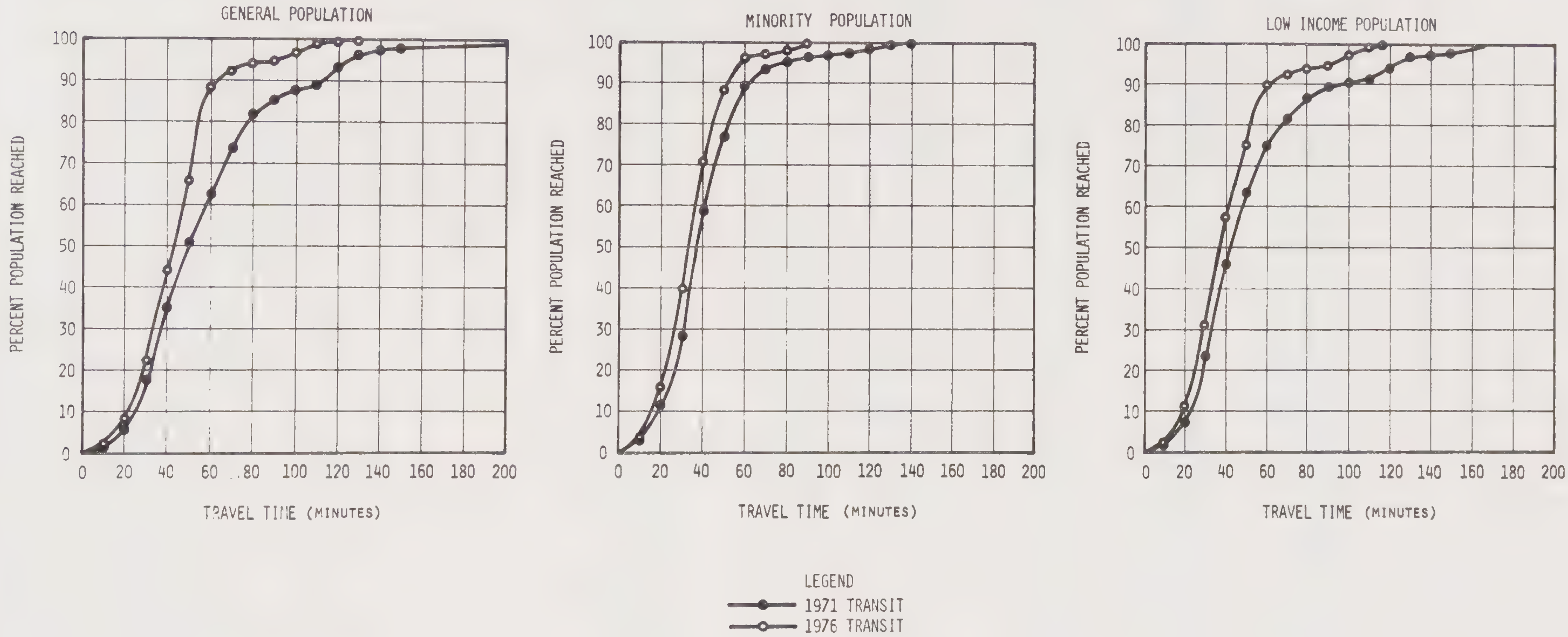
6. "Population, Employment and Land Use Projections-San Francisco Bay Region: 1970-2000, Summary of Series 2 Projections," Joint Land Use/Transportation Planning Program, Association of Bay Area Governments and Metropolitan Transportation Commission, August 1973.

Appendix B

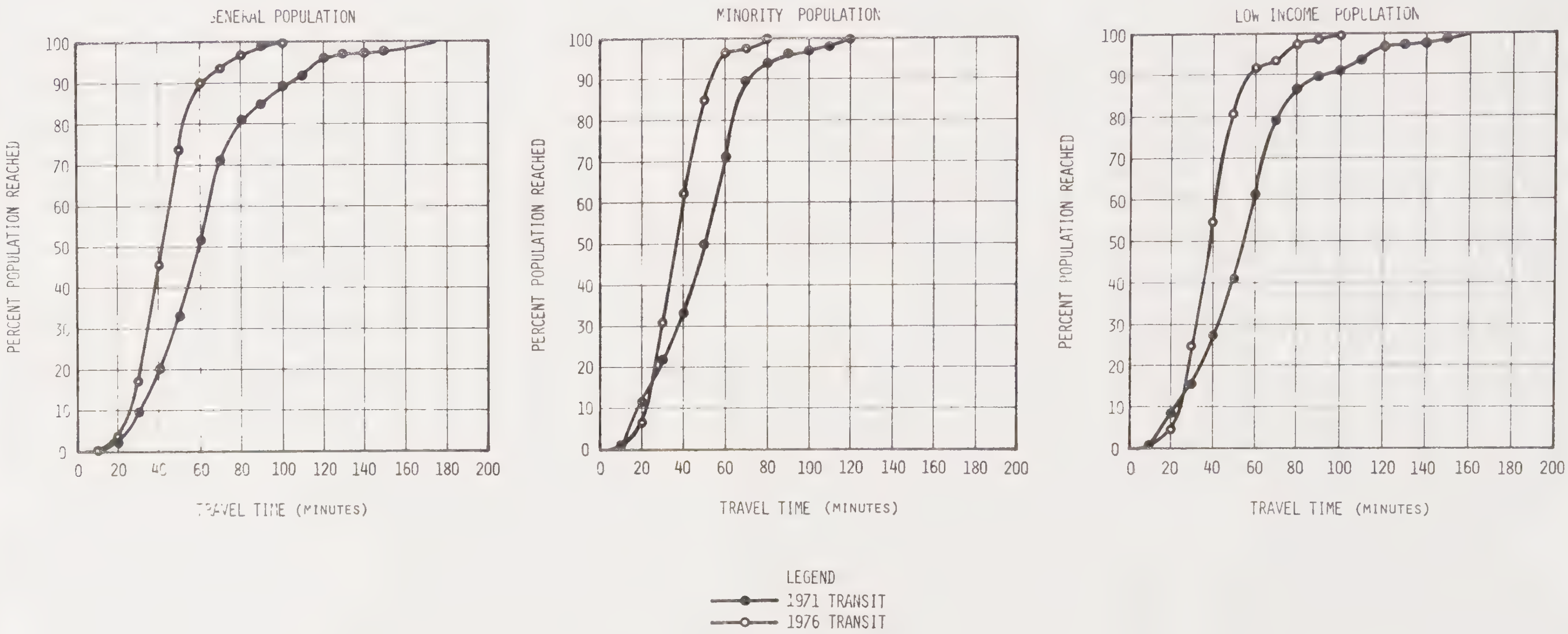
SUPPLEMENTAL GRAPHICS



GRAPH 1

CHANGES IN EMPLOYMENT ACCESSIBILITY TO SAN FRANCISCO CBD FOR DIFFERENT POPULATION GROUPS

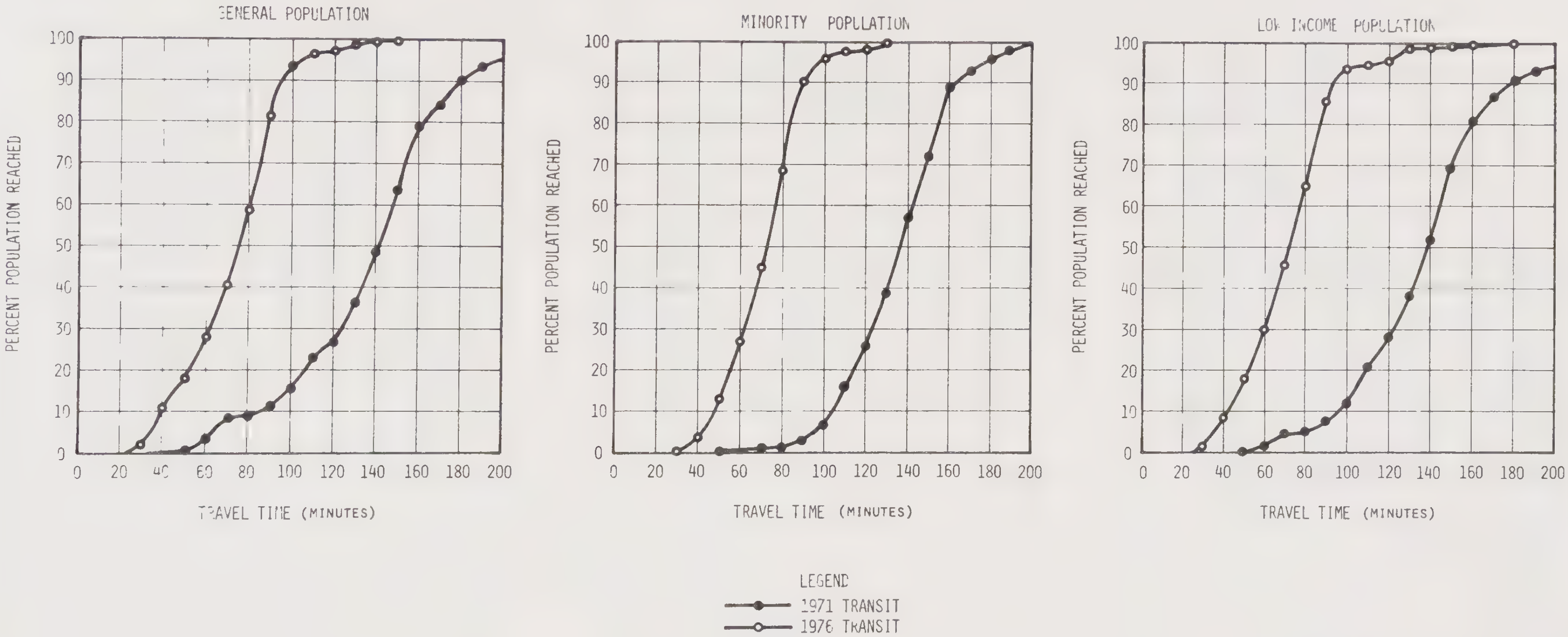
(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM AND 1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 2

CHANGES IN EMPLOYMENT ACCESSIBILITY TO OAKLAND CBD FOR DIFFERENT POPULATION GROUPS

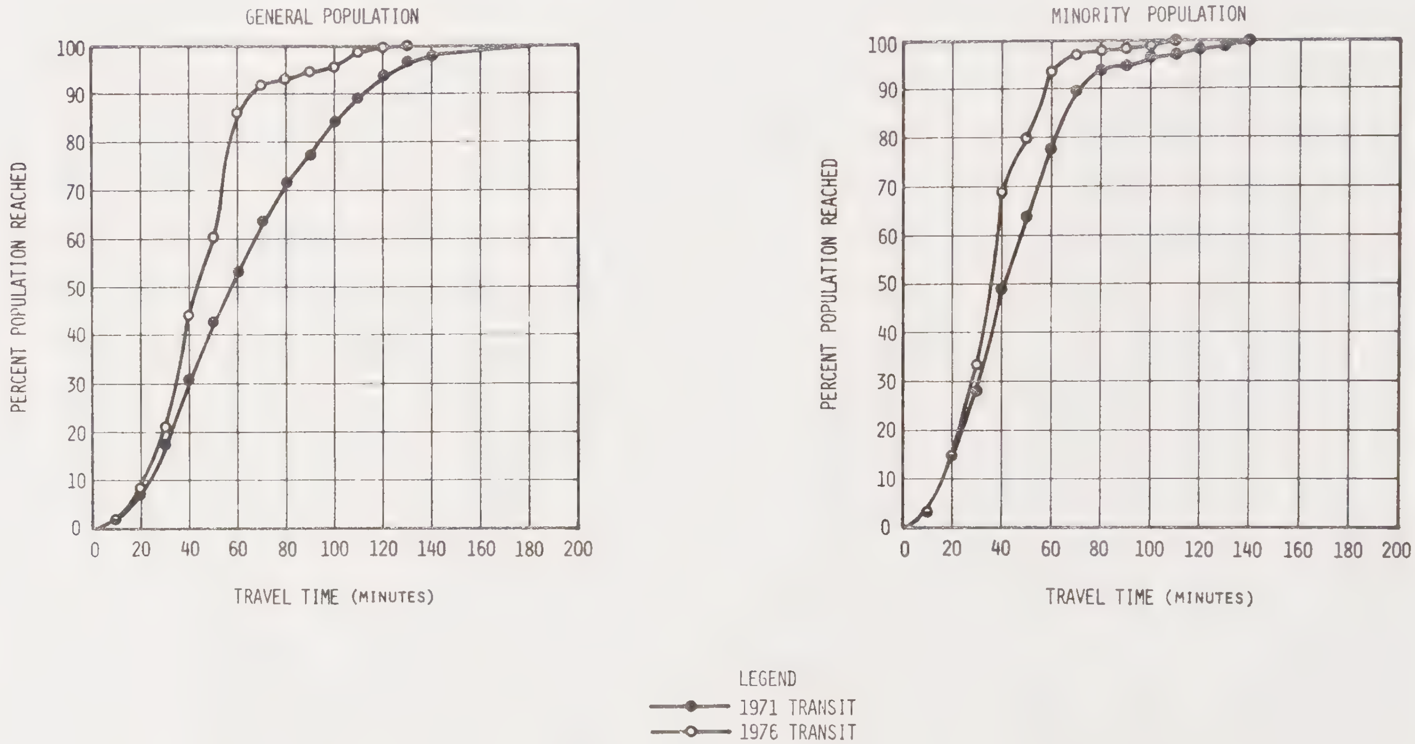
(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM AND 1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 3

CHANGES IN EMPLOYMENT ACCESSIBILITY TO FREMONT GENERAL MOTORS PLANT FOR DIFFERENT POPULATION GROUPS

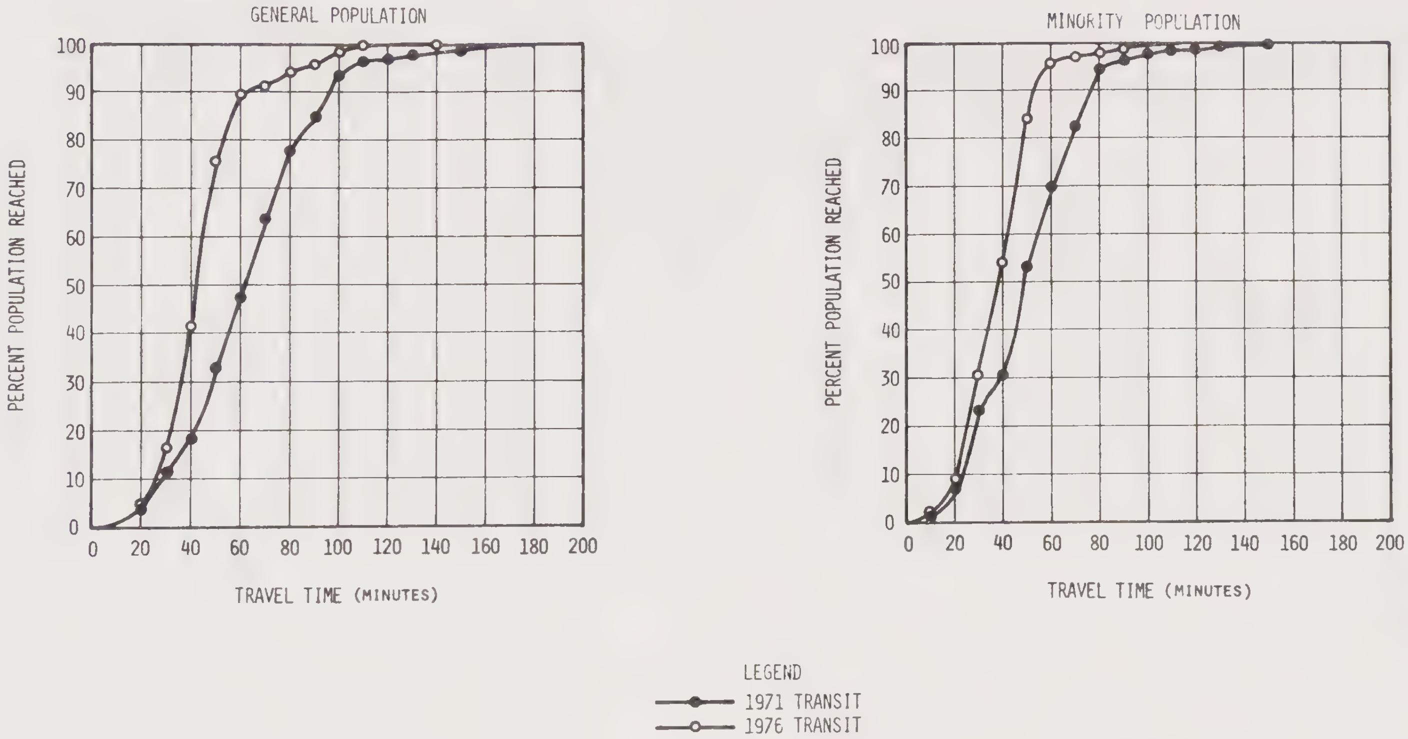
(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM AND 1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 4

CHANGES IN SHOPPING ACCESSIBILITY TO SAN FRANCISCO CBD FOR DIFFERENT POPULATION GROUPS

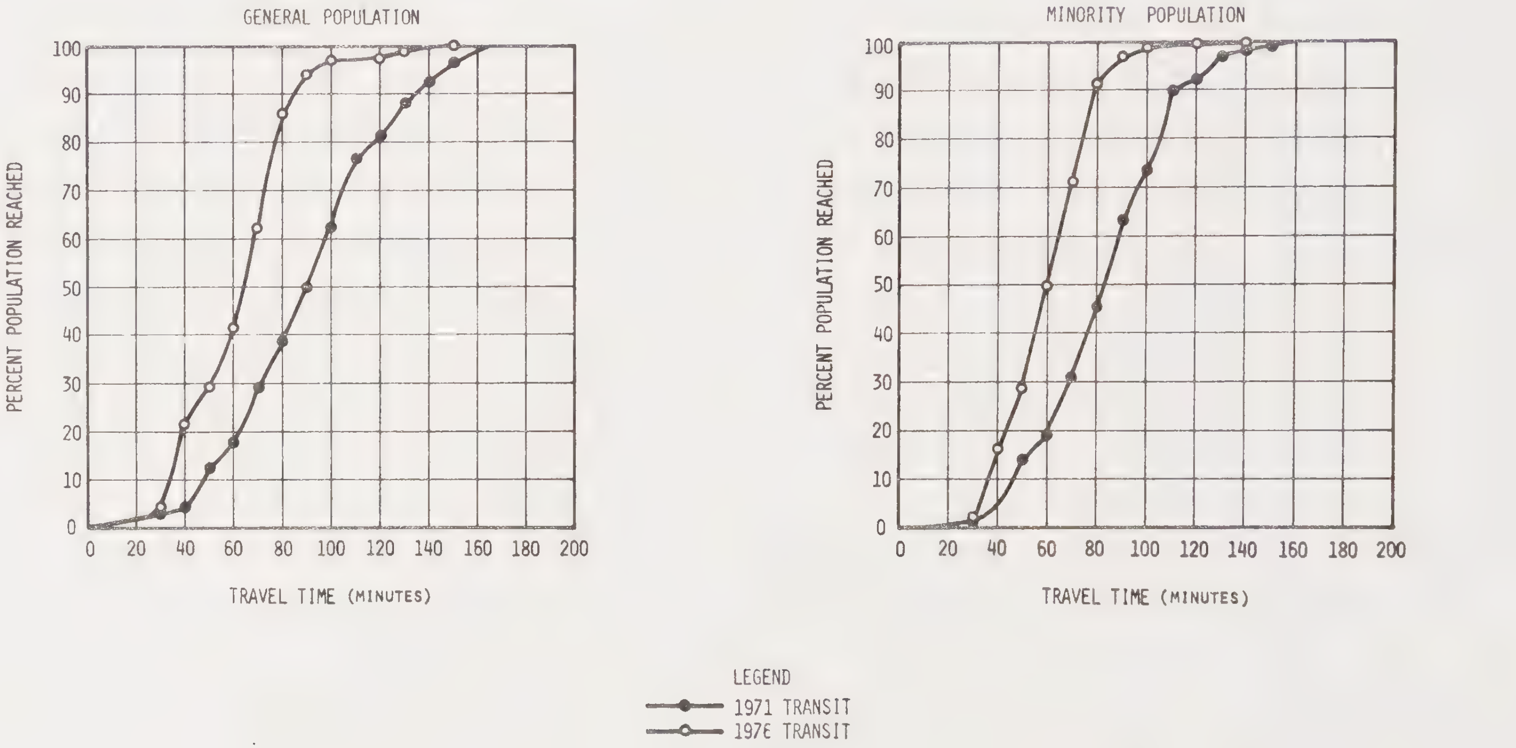
(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR OFF-PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM AND 1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 5

CHANGES IN SHOPPING ACCESSIBILITY TO OAKLAND CBD FOR DIFFERENT POPULATION GROUPS

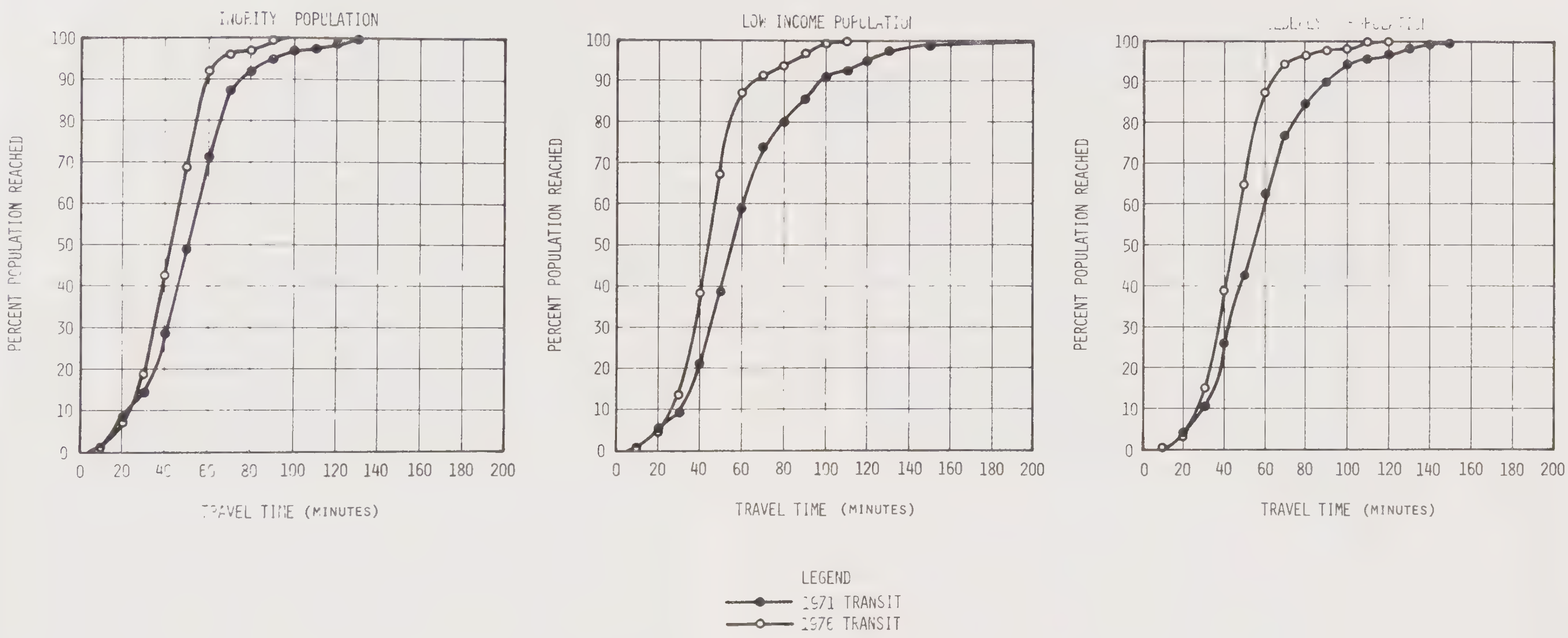
(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR OFF-PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM AND 1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 6

CHANGES IN SHOPPING ACCESSIBILITY TO BAY FAIR SHOPPING CENTER FOR DIFFERENT POPULATION GROUPS

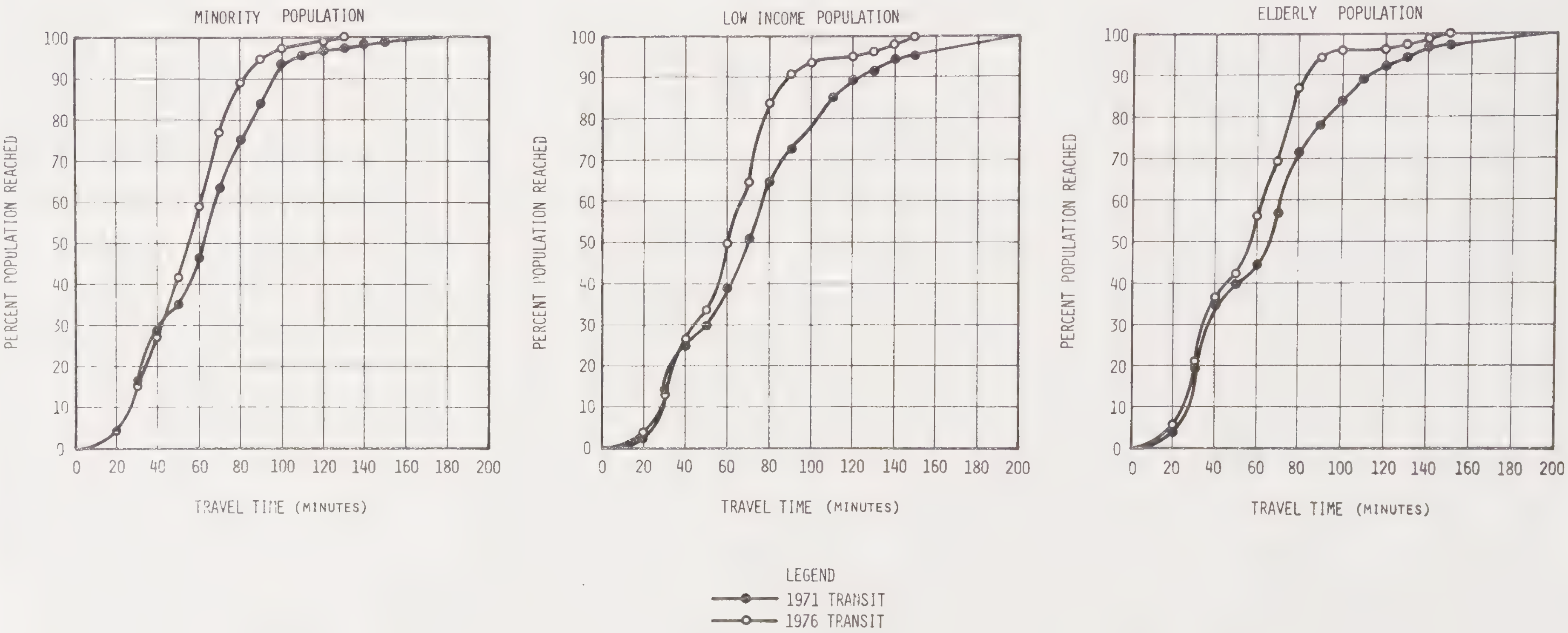
(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR OFF-PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM AND 1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 7

CHANGES IN HEALTH CARE ACCESSIBILITY TO OAKLAND KAISER HOSPITAL FOR DIFFERENT POPULATION GROUPS

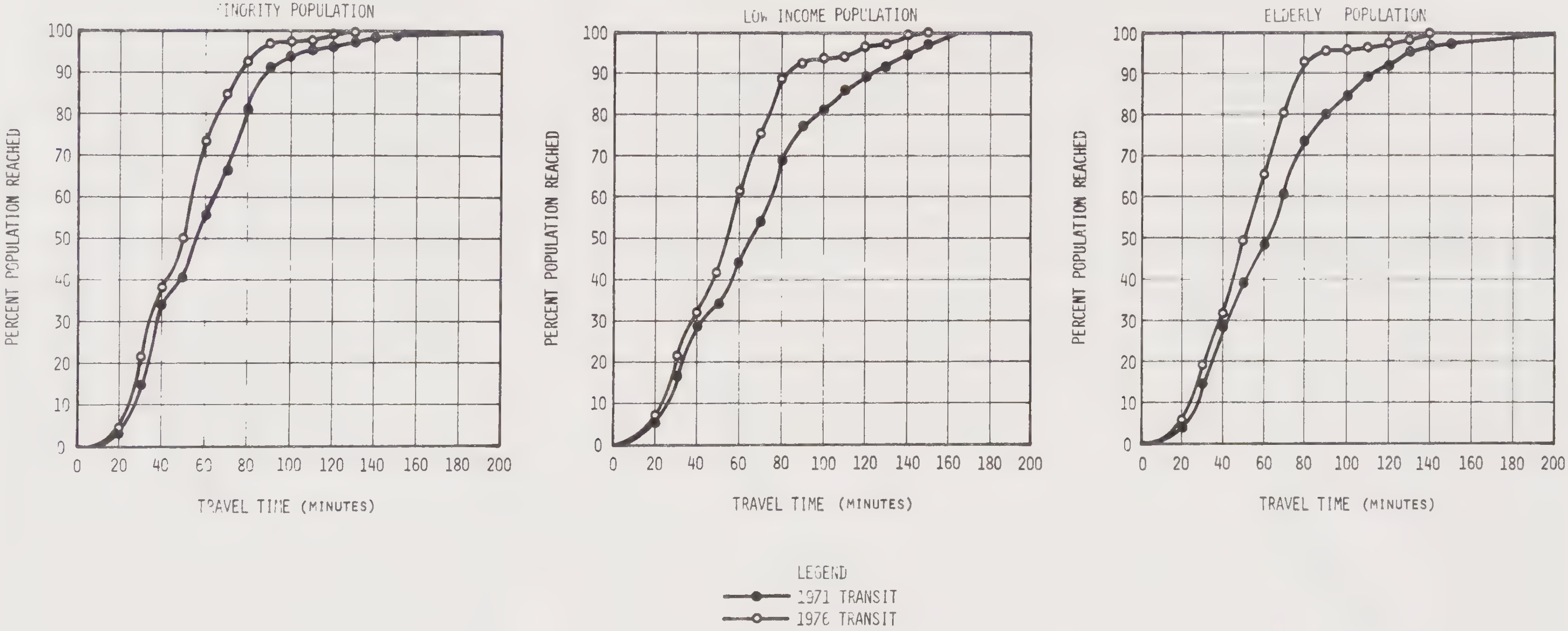
(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR OFF-PEAK PERIOD
ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM AND
1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 8

CHANGES IN HEALTH CARE ACCESSIBILITY TO UNIVERSITY OF CALIFORNIA MEDICAL CENTER FOR DIFFERENT POPULATION GROUPS

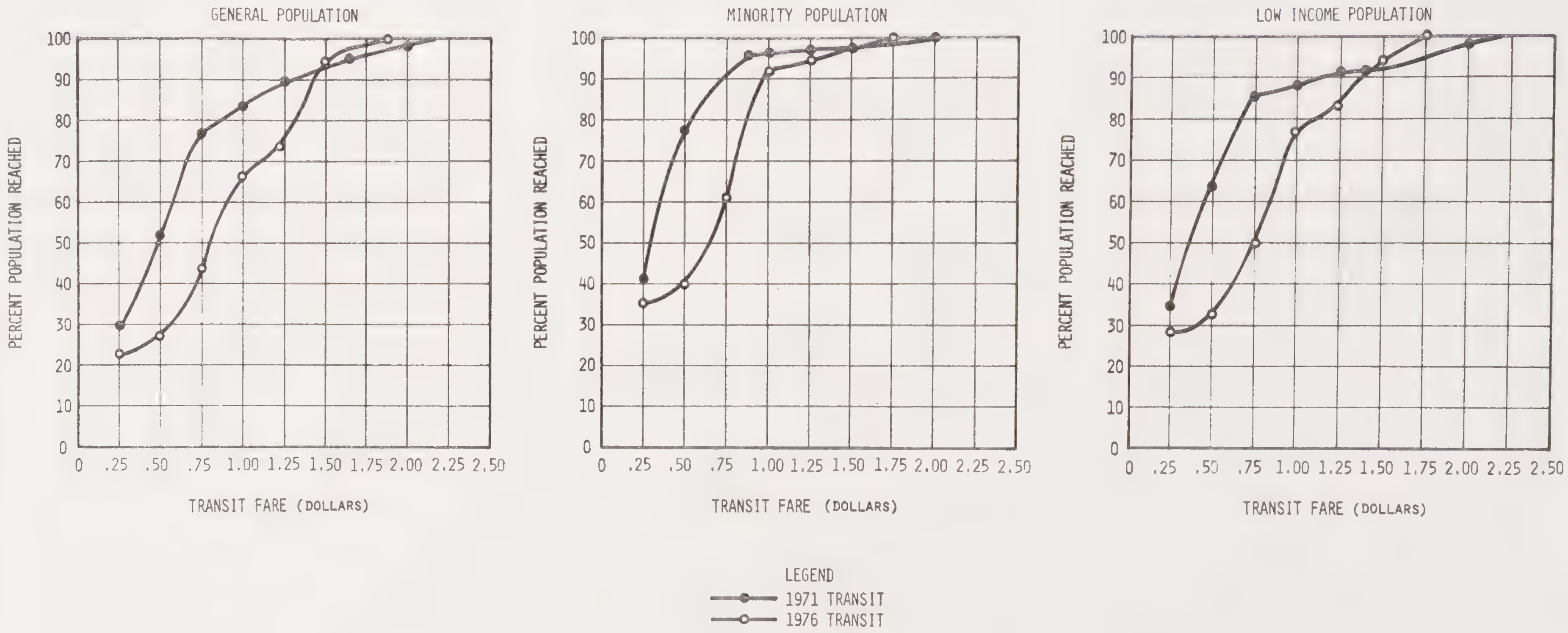
(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR OFF-PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM AND 1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 9

CHANGES IN HEALTH CARE ACCESSIBILITY TO SAN FRANCISCO GENERAL HOSPITAL FOR DIFFERENT POPULATION GROUPS

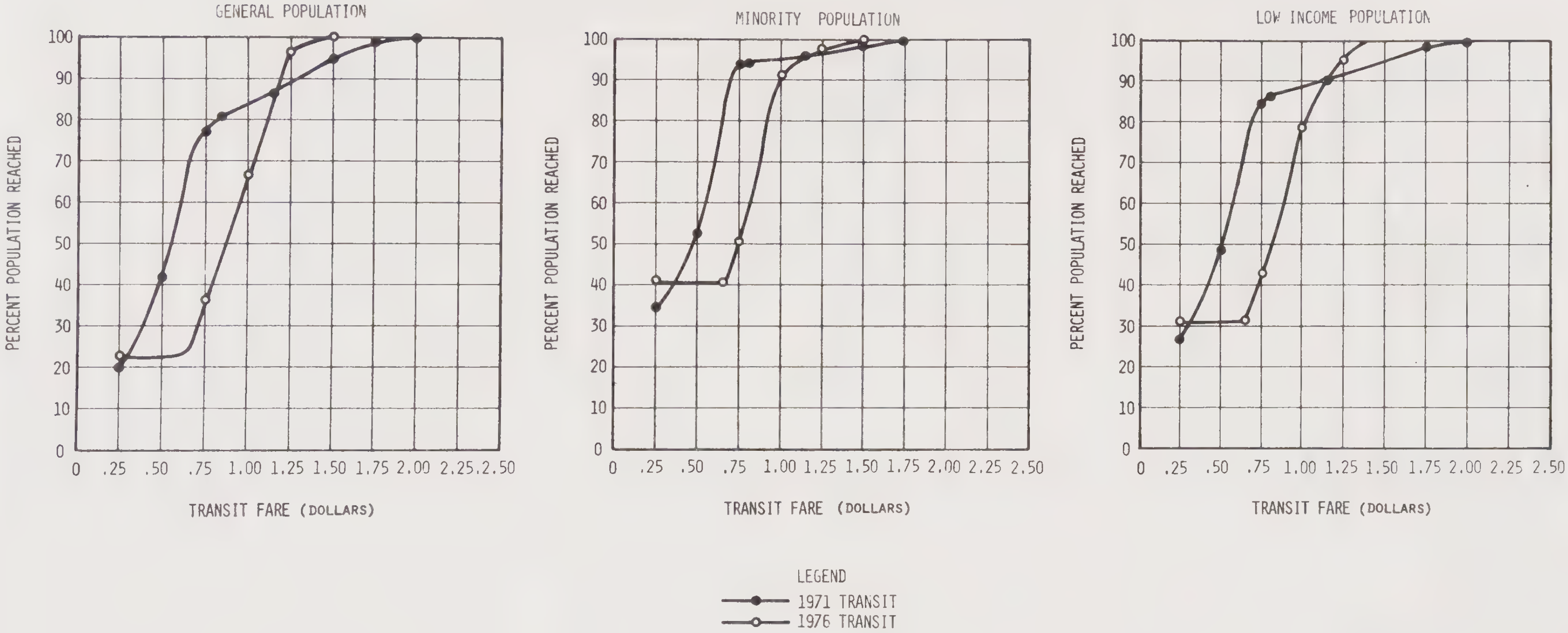
(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR OFF-PEAK PERIOD ZONE-TO-ZONE TRAVEL TIMES, 1976 (POST-BART) TRANSIT SYSTEM AND 1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 10

CHANGES IN EMPLOYMENT ACCESSIBILITY TO SAN FRANCISCO CBD FOR DIFFERENT POPULATION GROUPS

(CHANGES IN PERCENTAGE OF POPULATION REACHED FOR PEAK PERIOD ZONE-TO-ZONE TRANSIT FARES, 1976 (POST-BART) TRANSIT SYSTEM AND 1971 (PRE-BART) TRANSIT SYSTEM)



GRAPH 11

CHANGES IN EMPLOYMENT ACCESSIBILITY TO OAKLAND CBD FOR DIFFERENT POPULATION GROUPS

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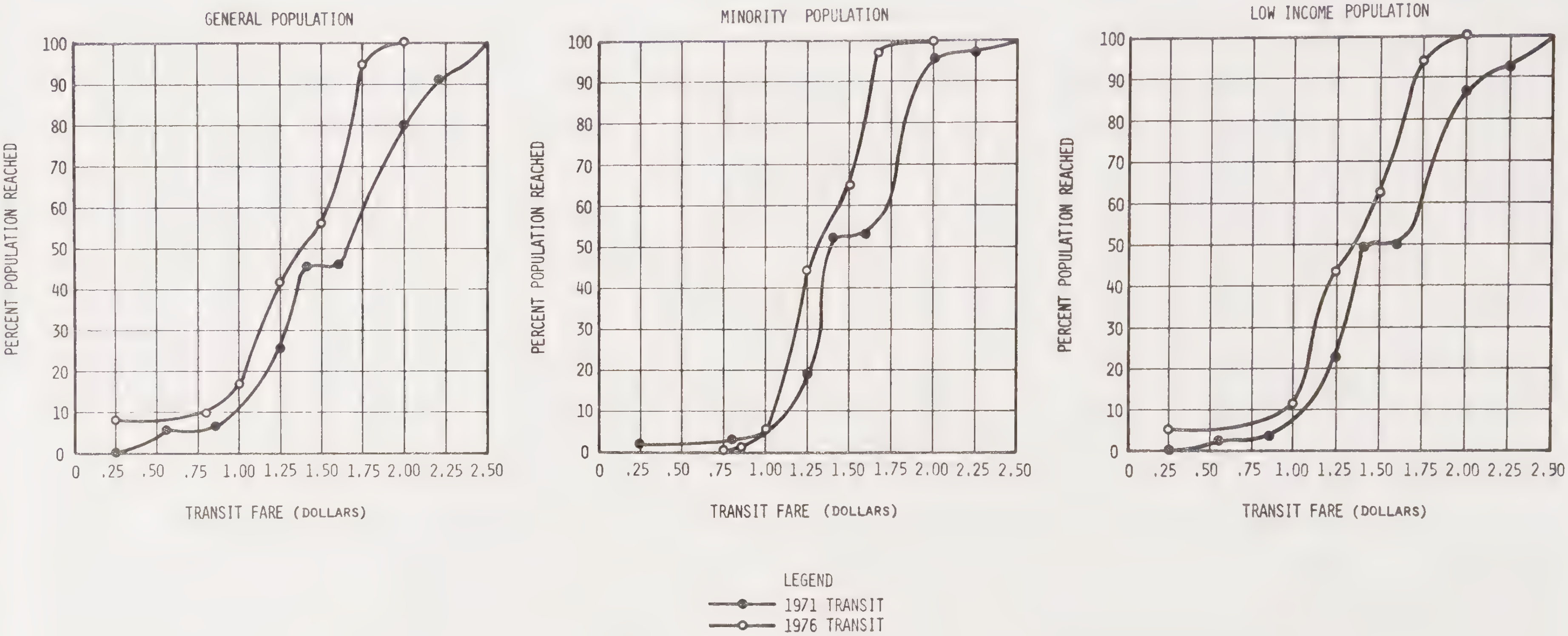

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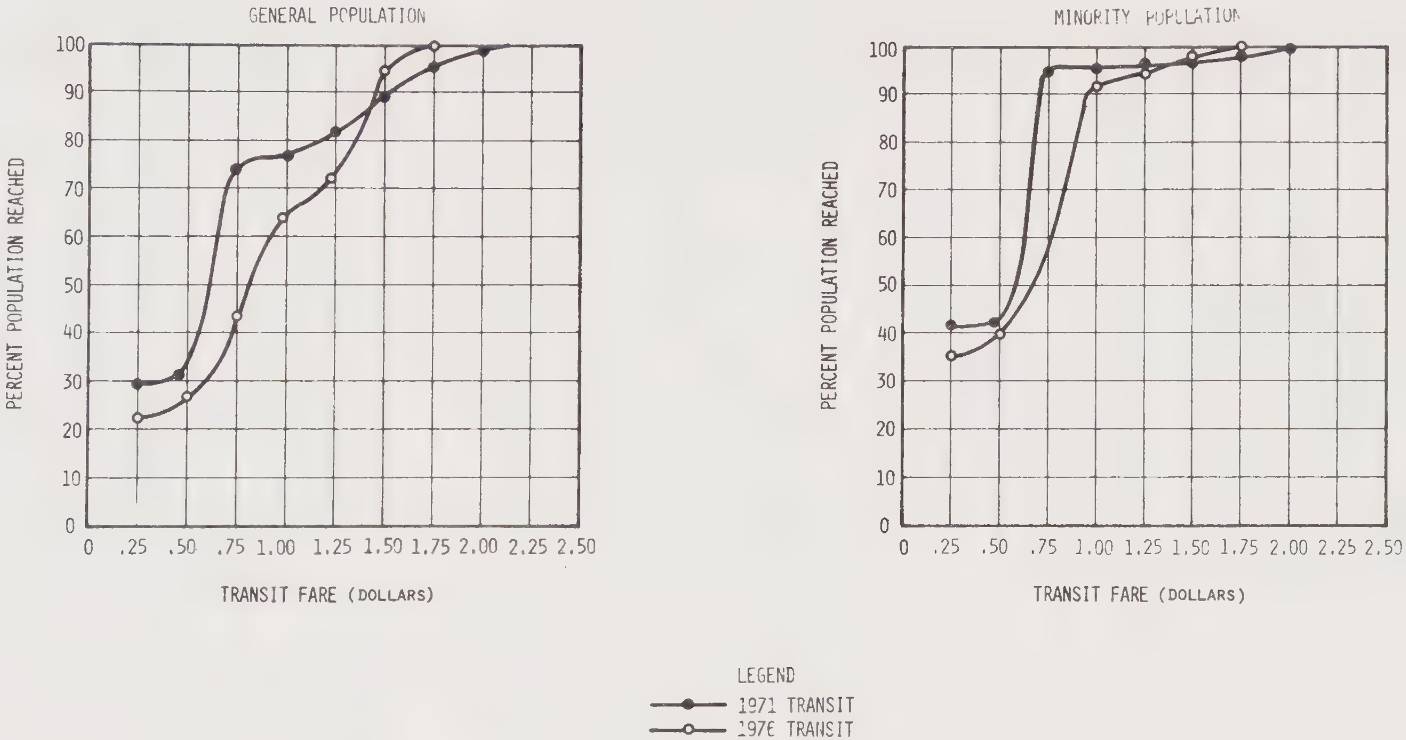

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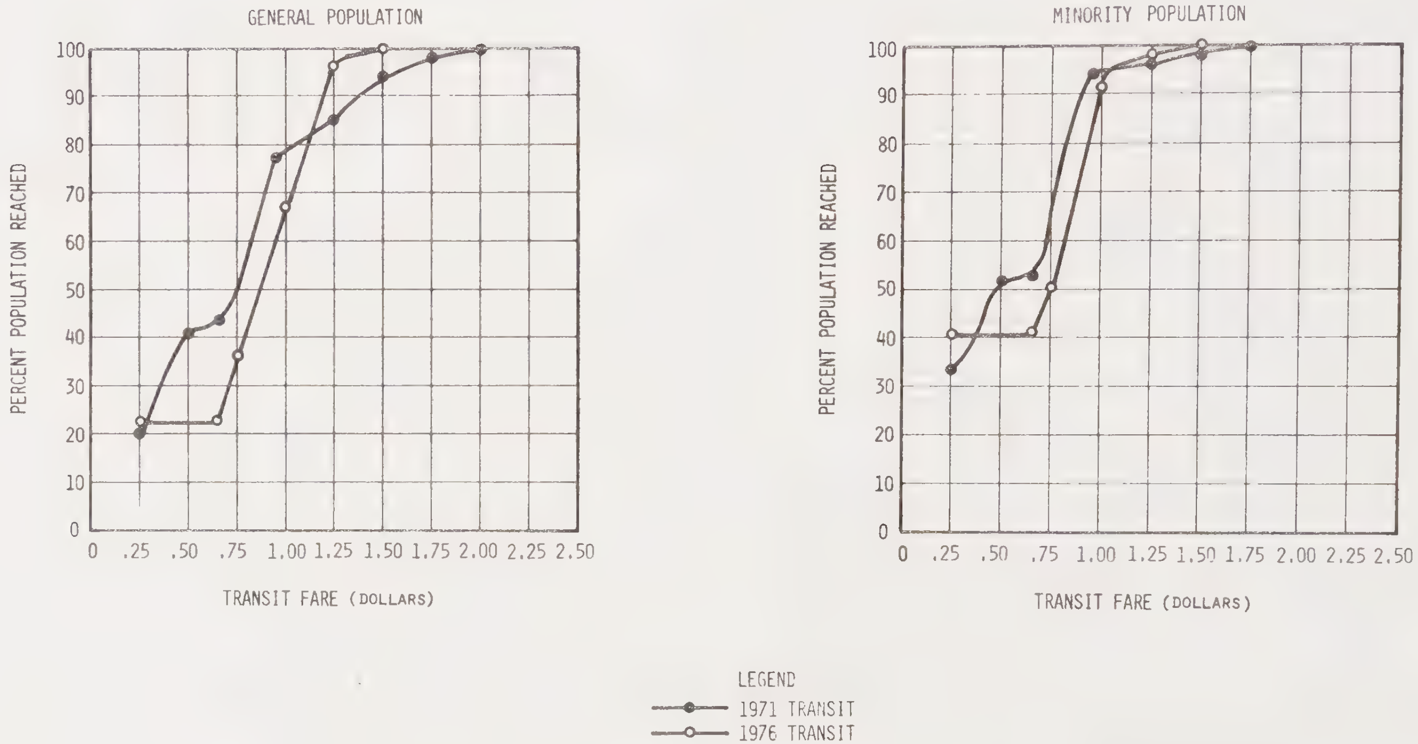

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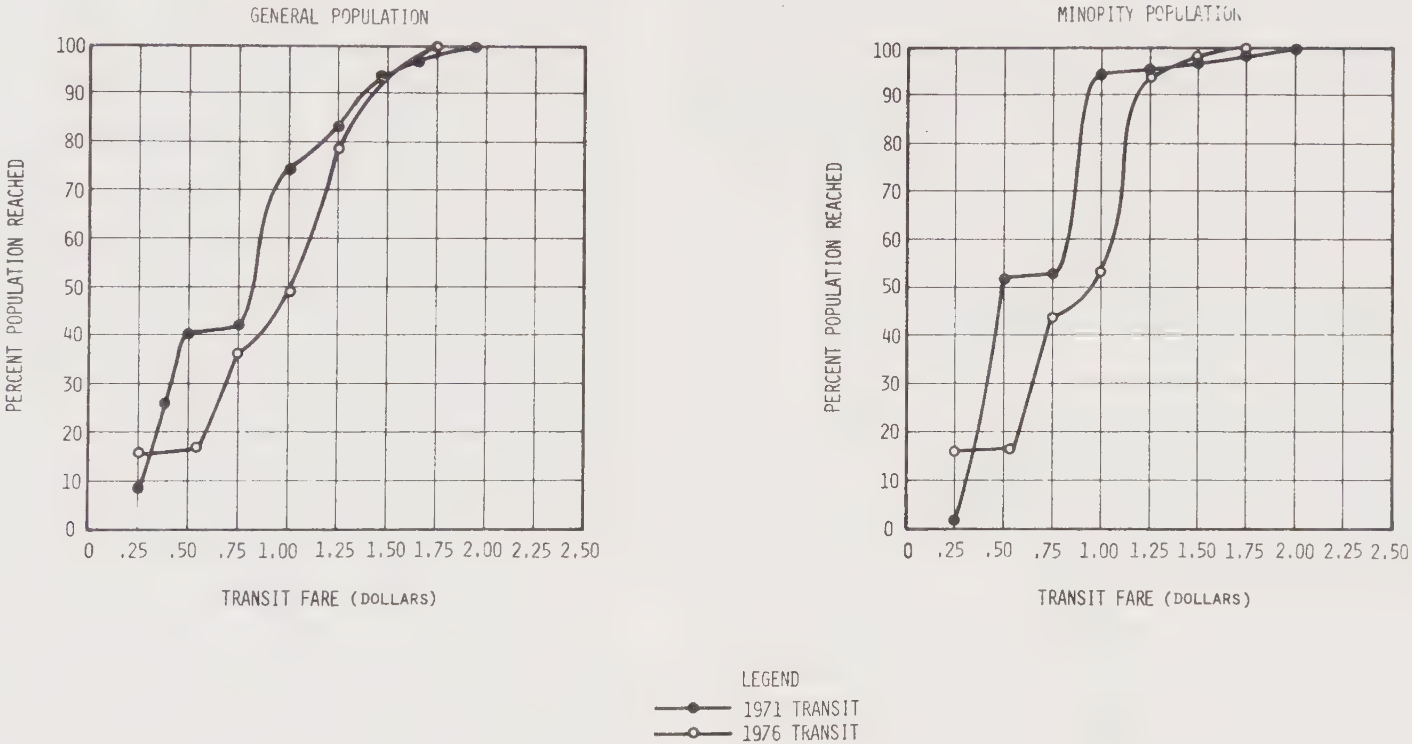

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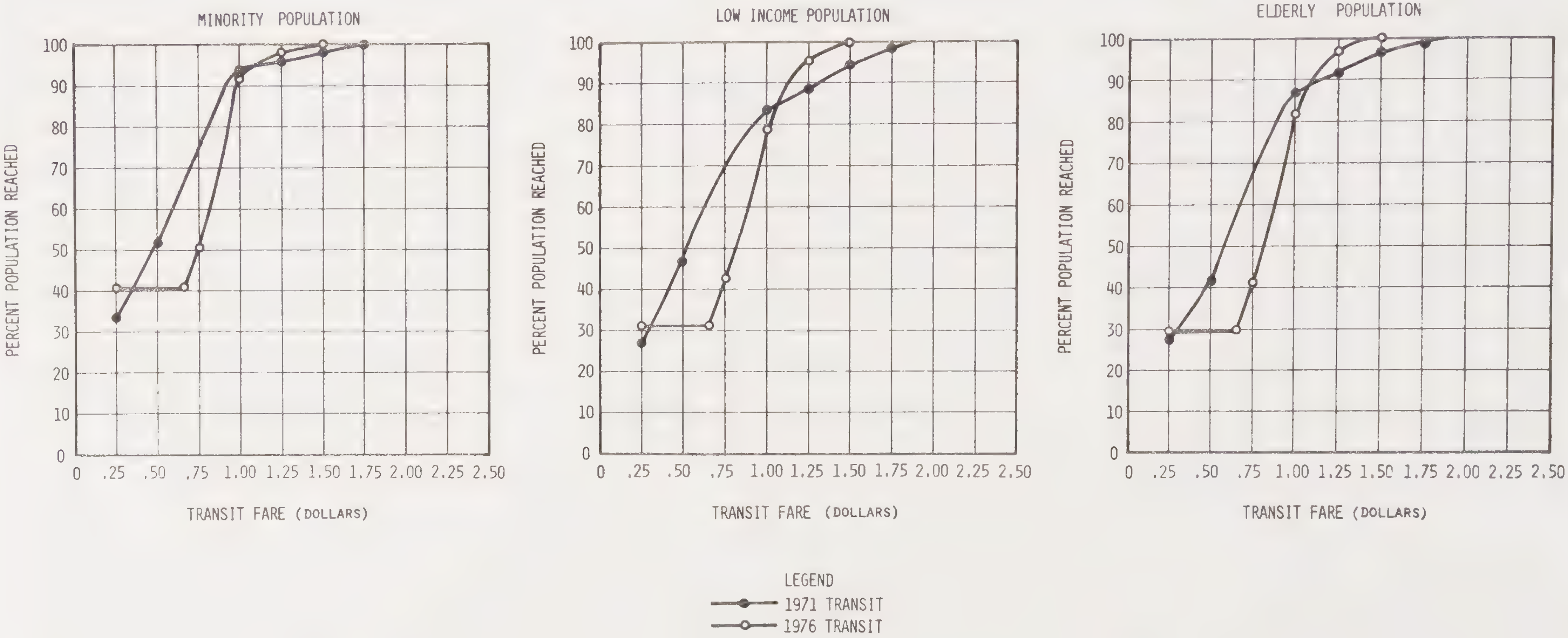

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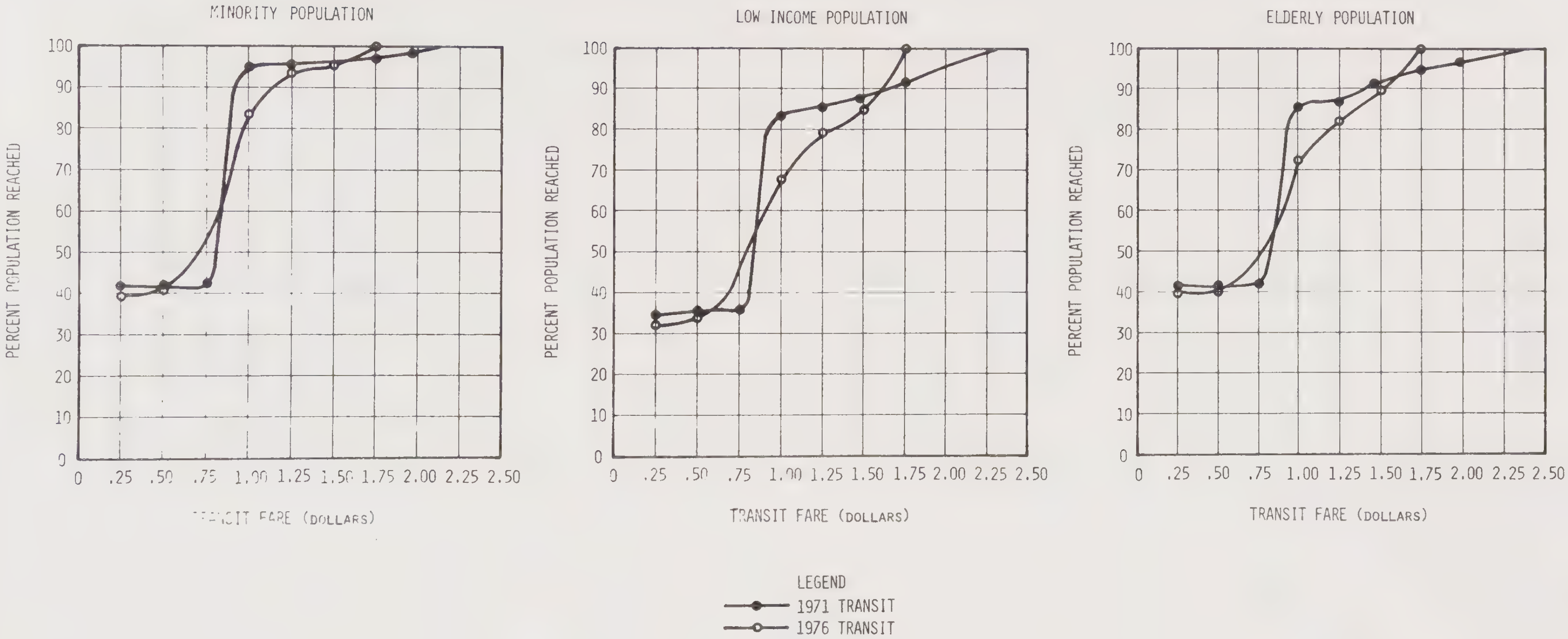

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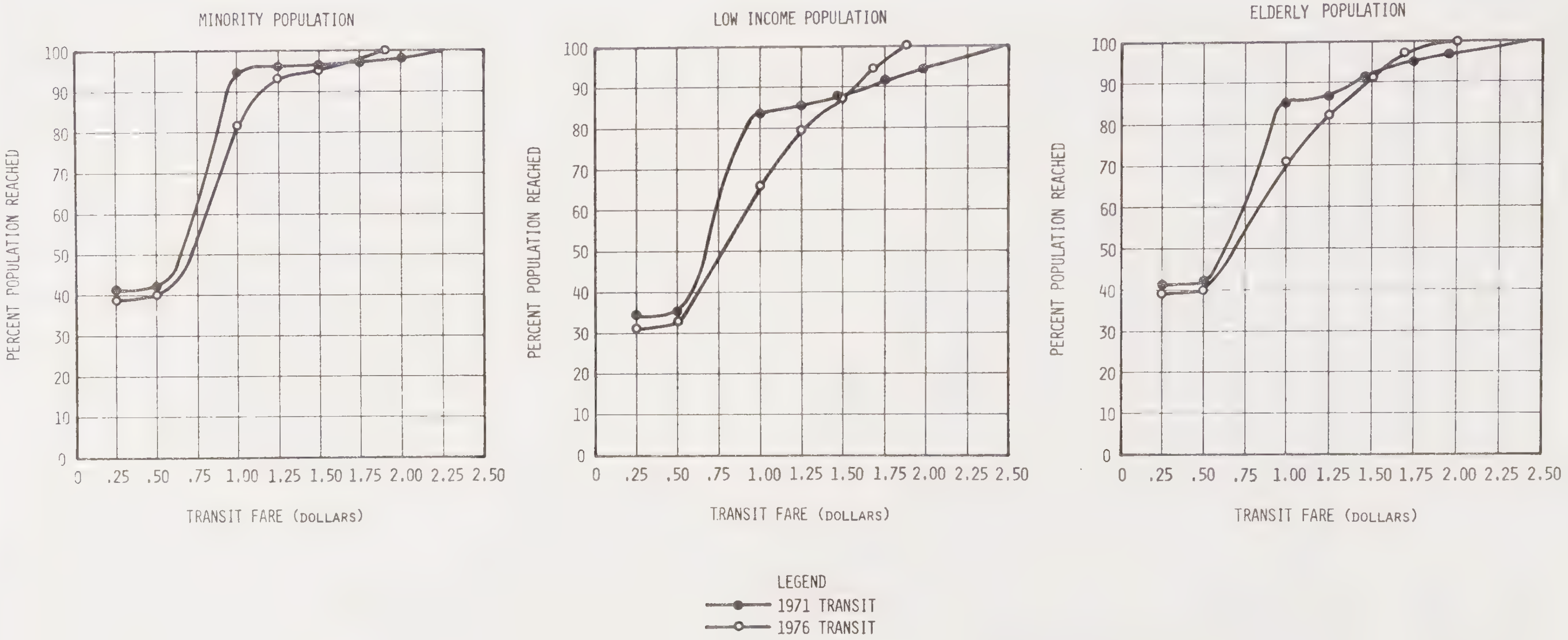

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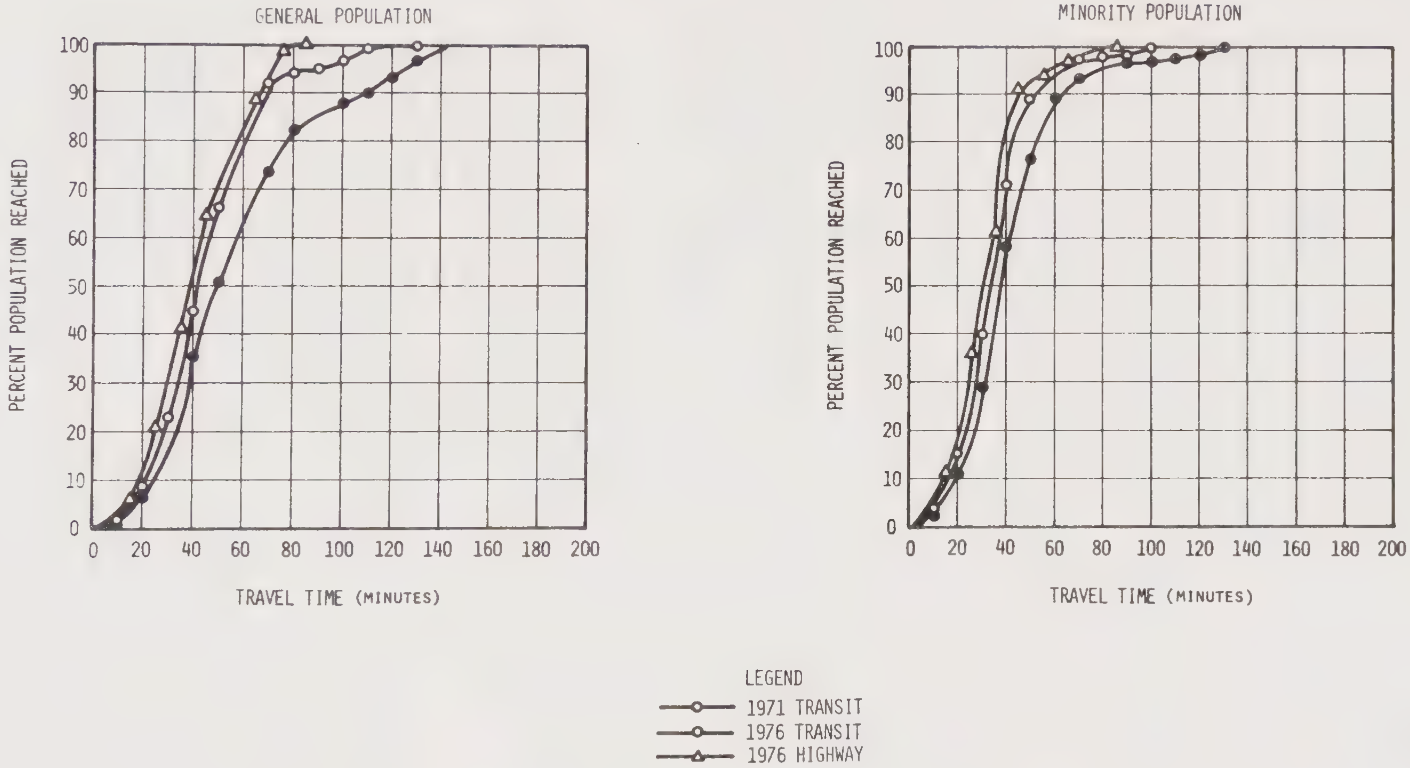

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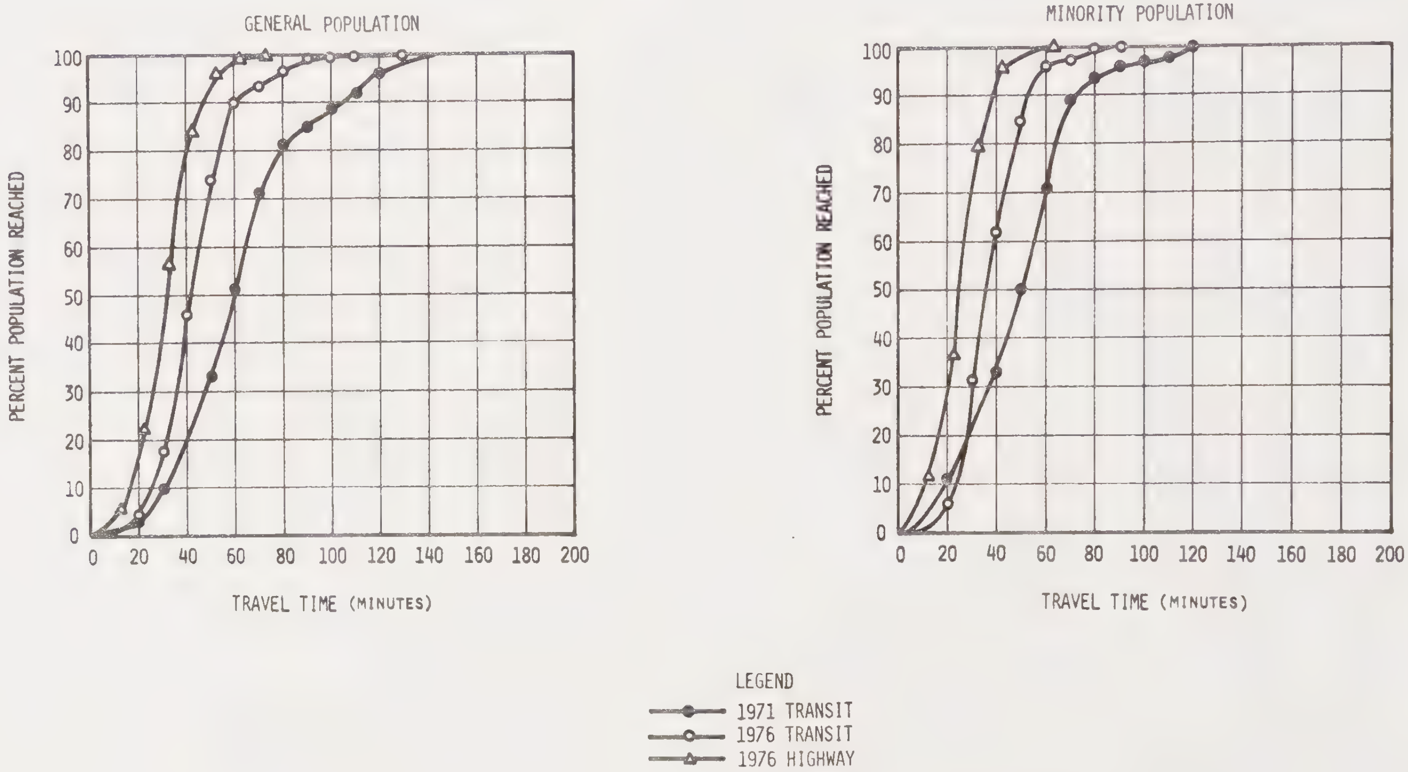

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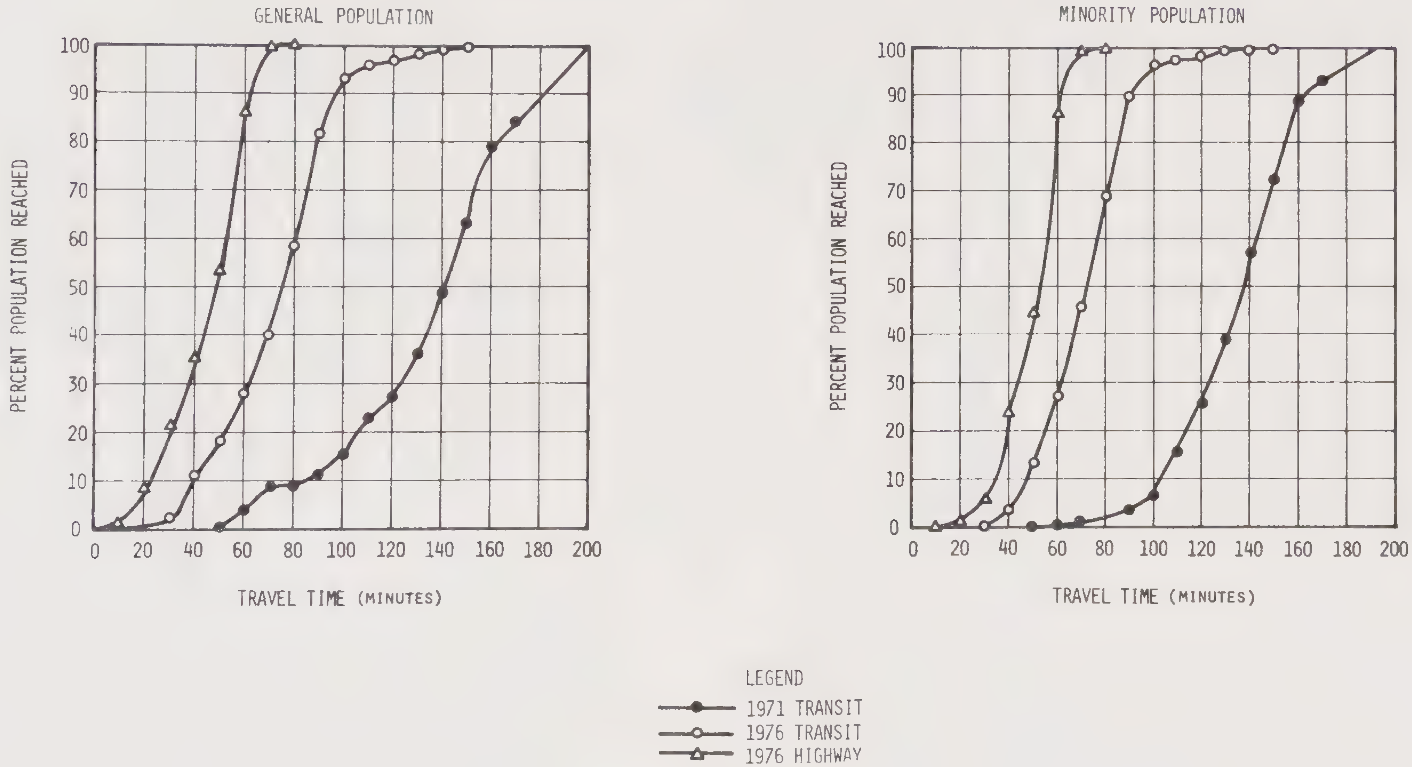

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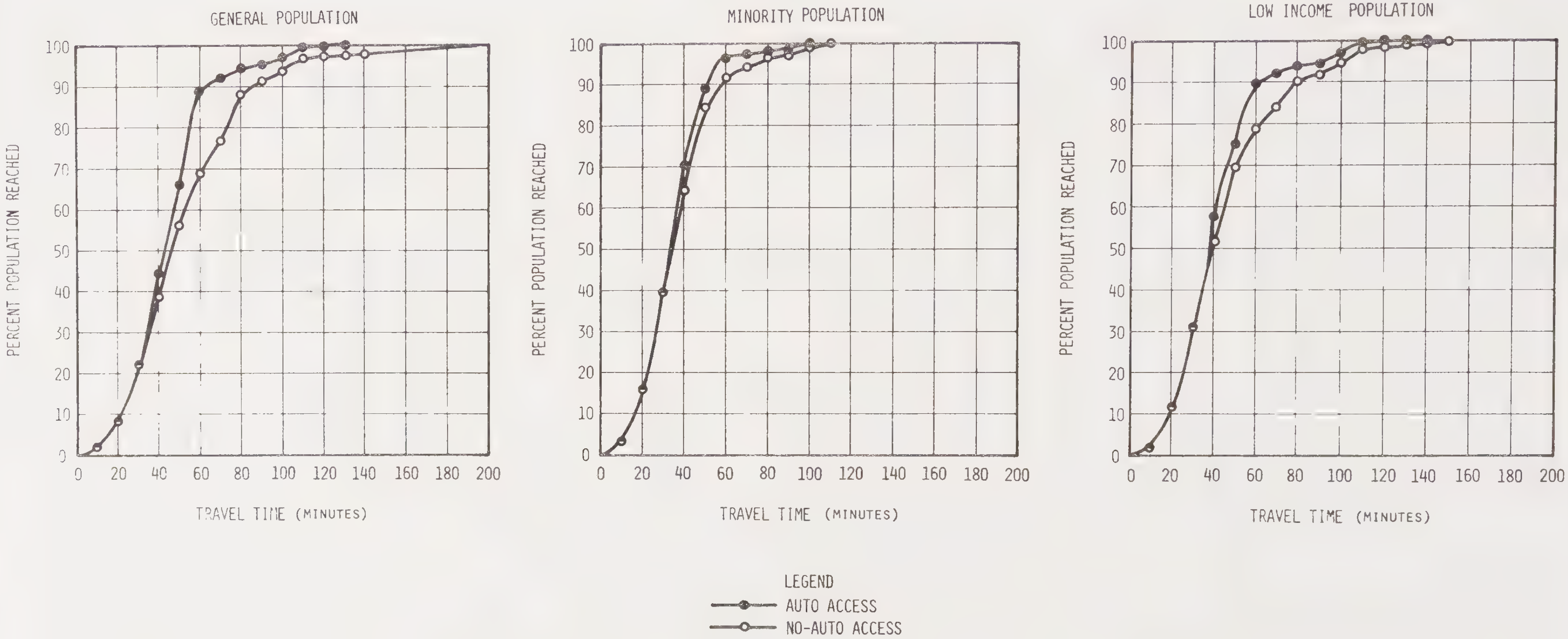

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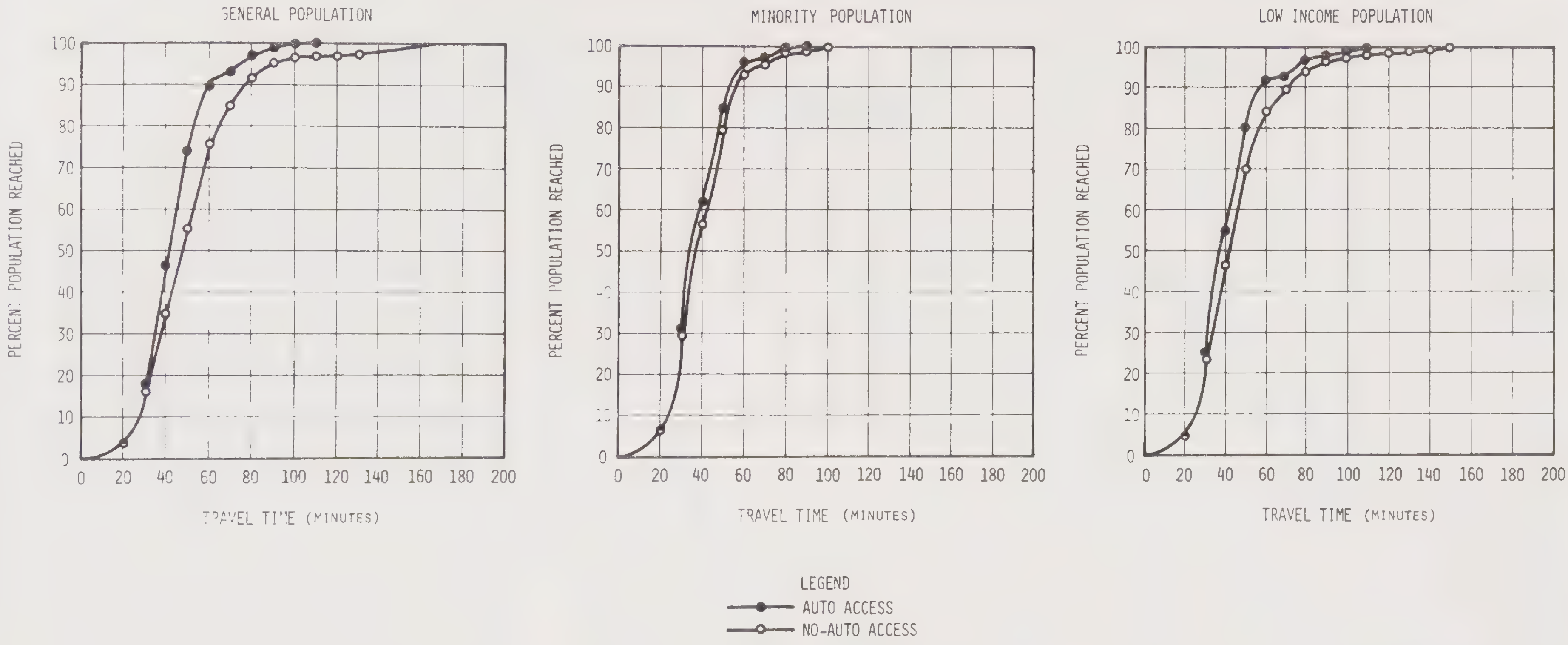

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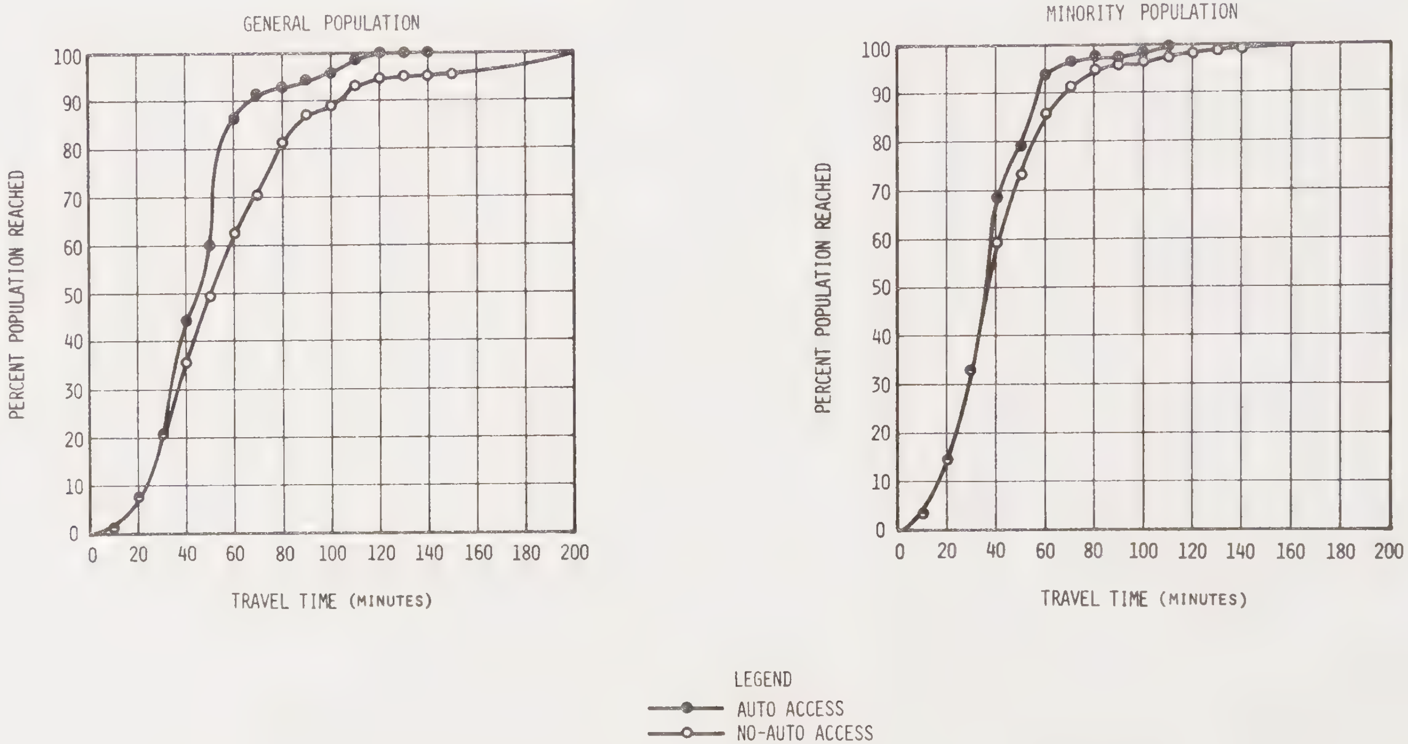

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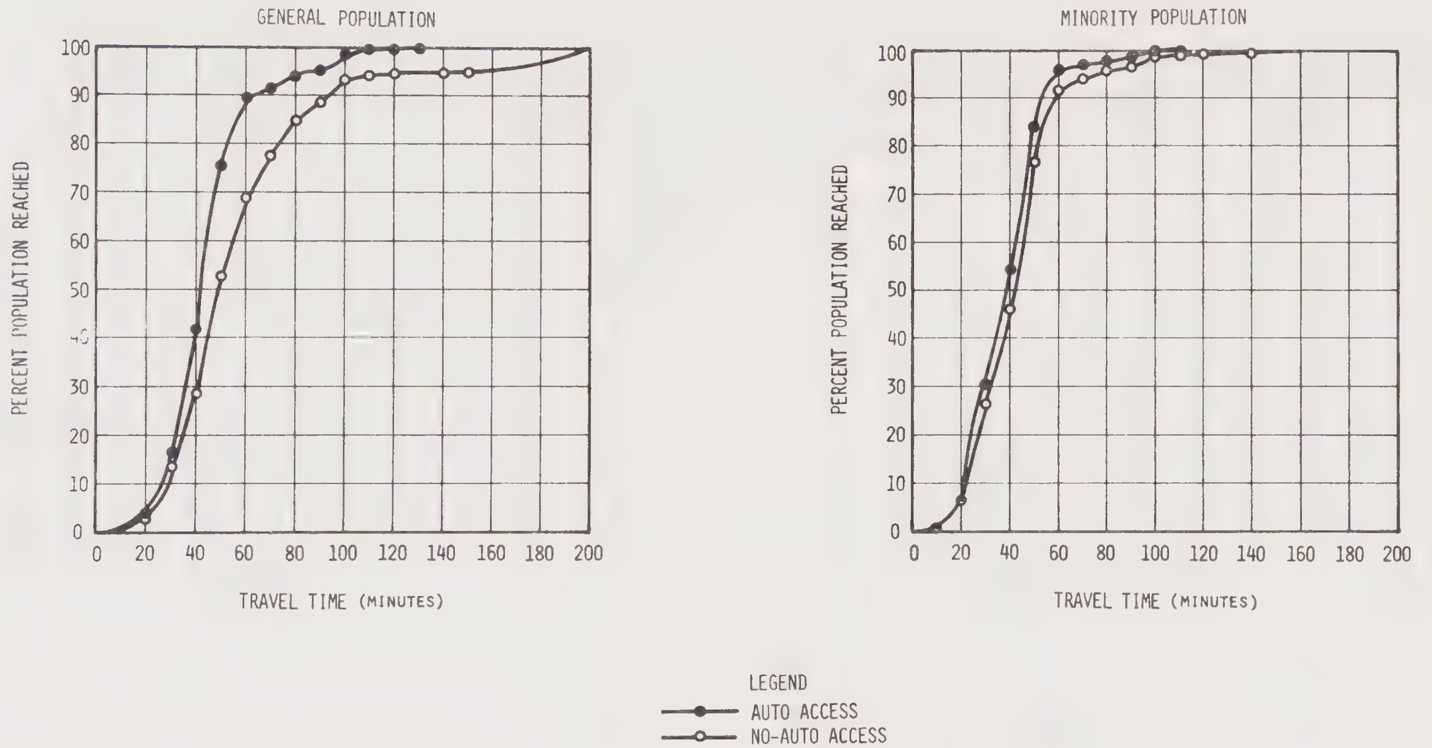

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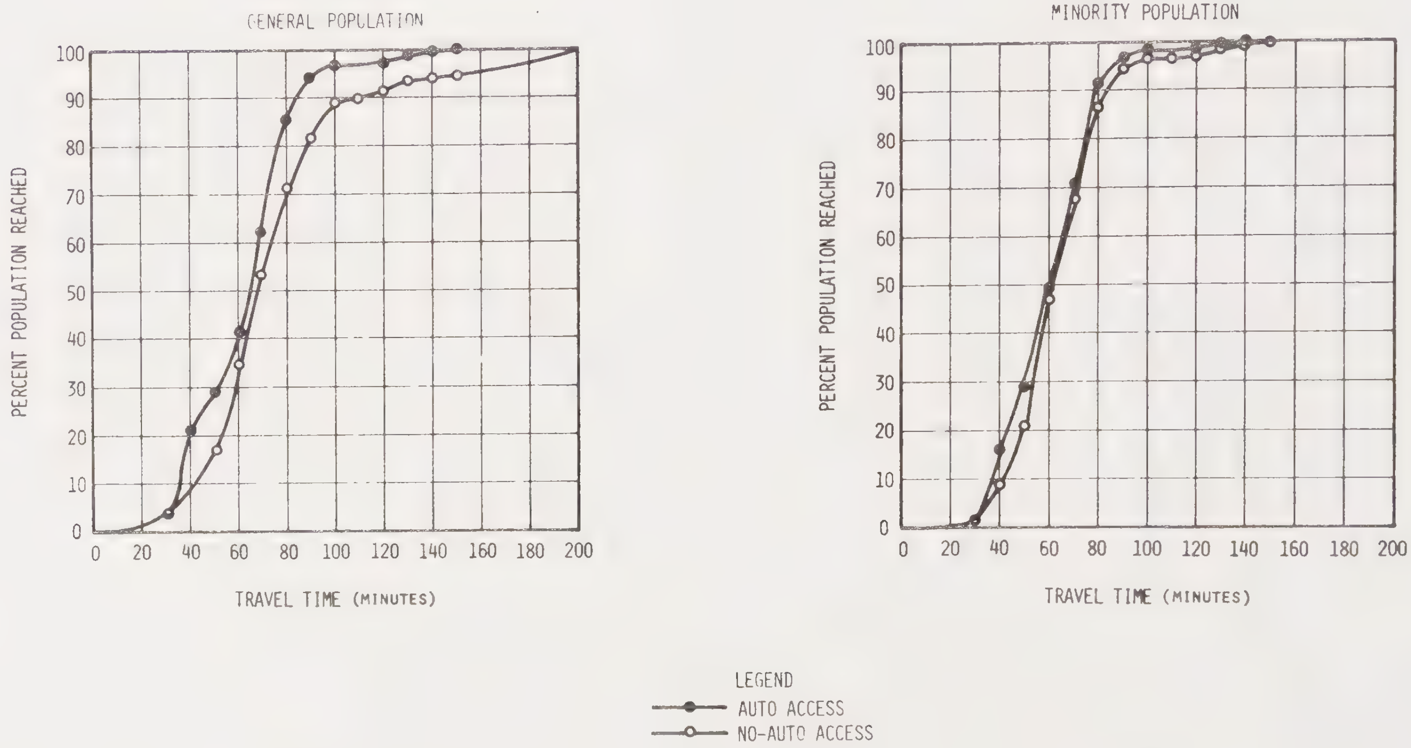

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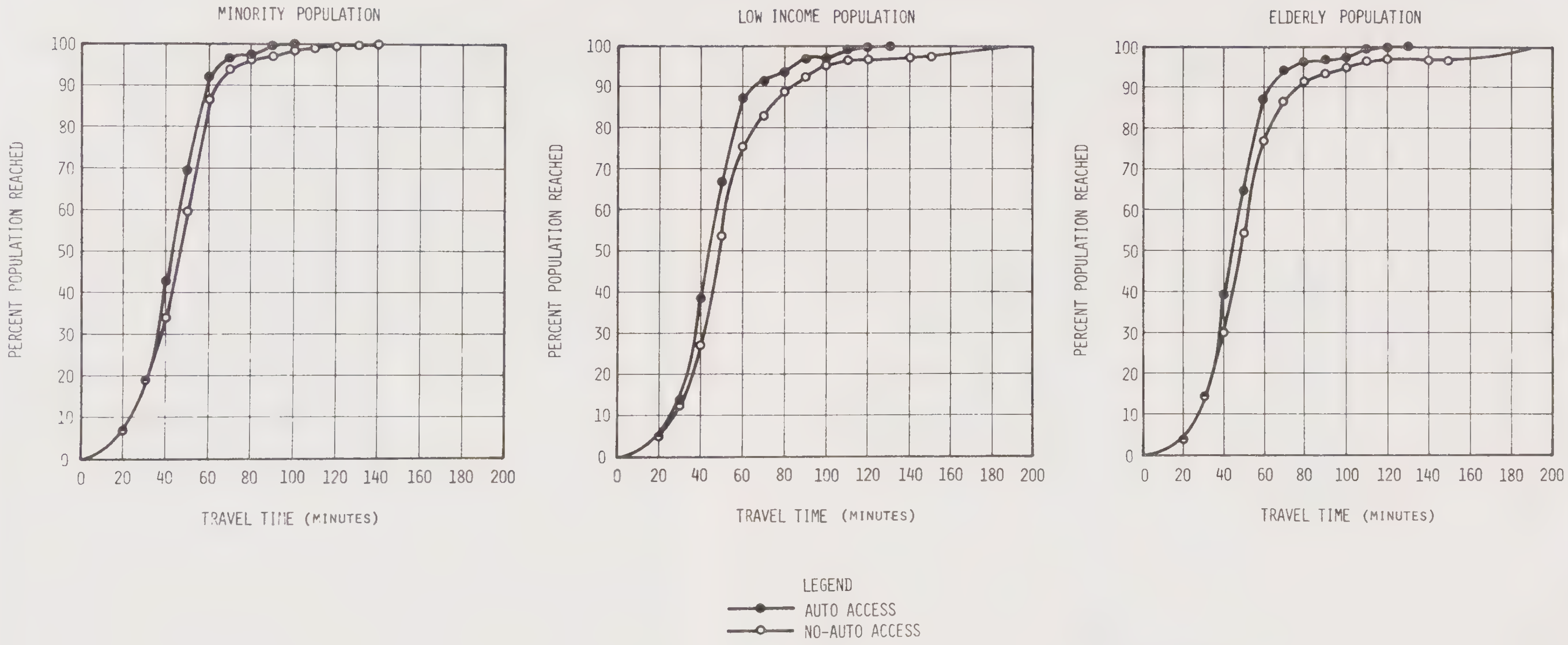

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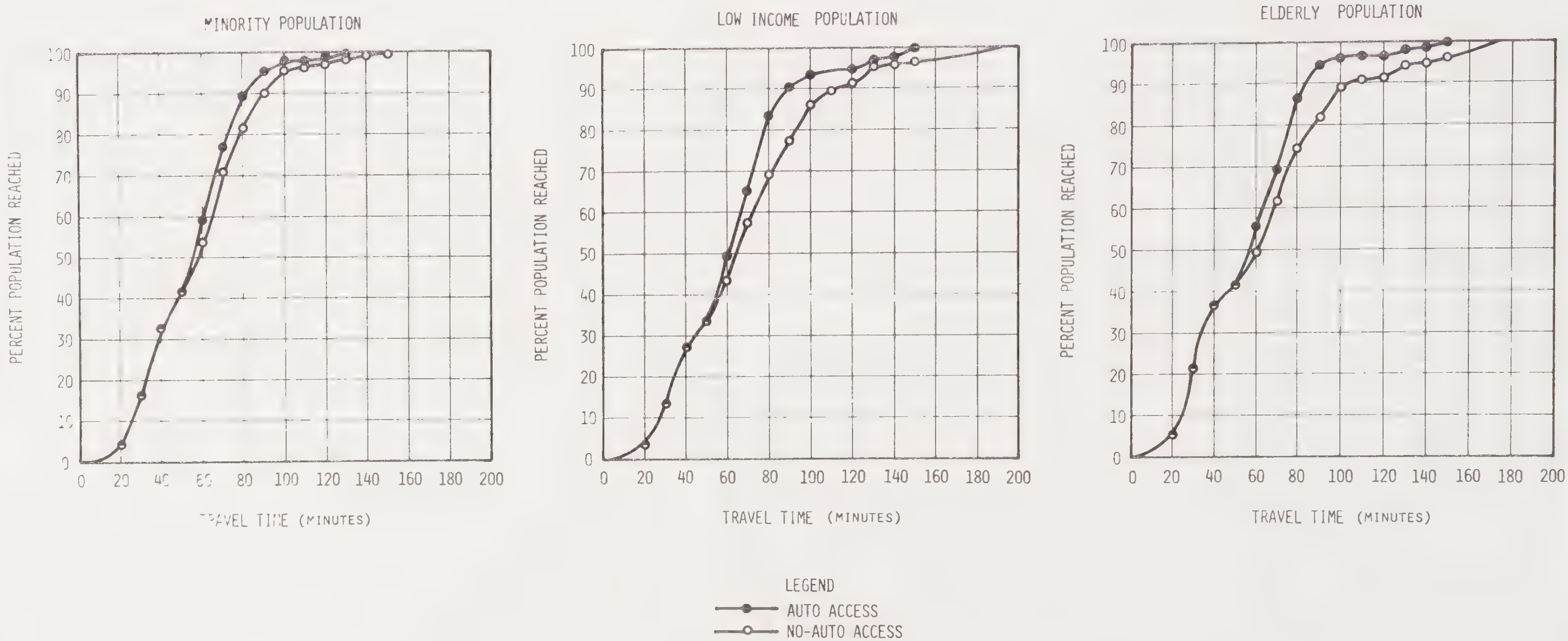

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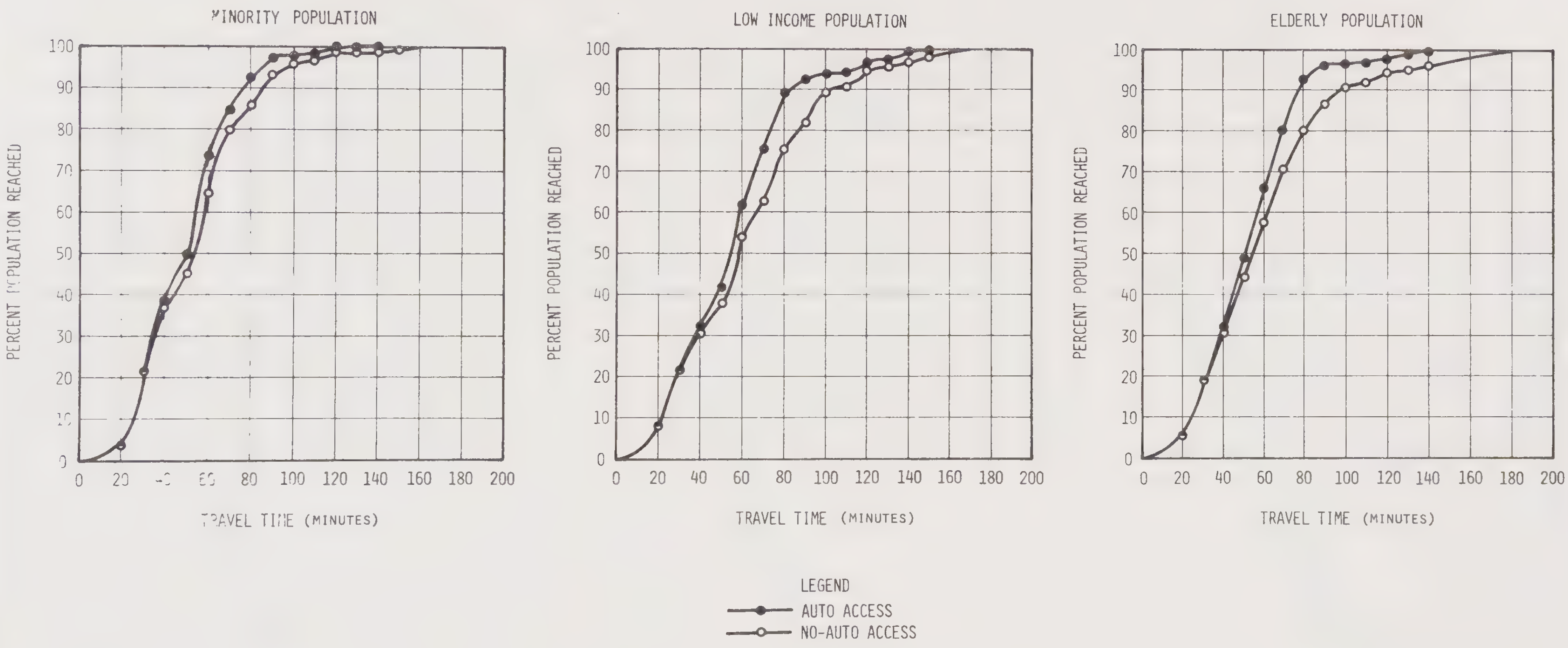

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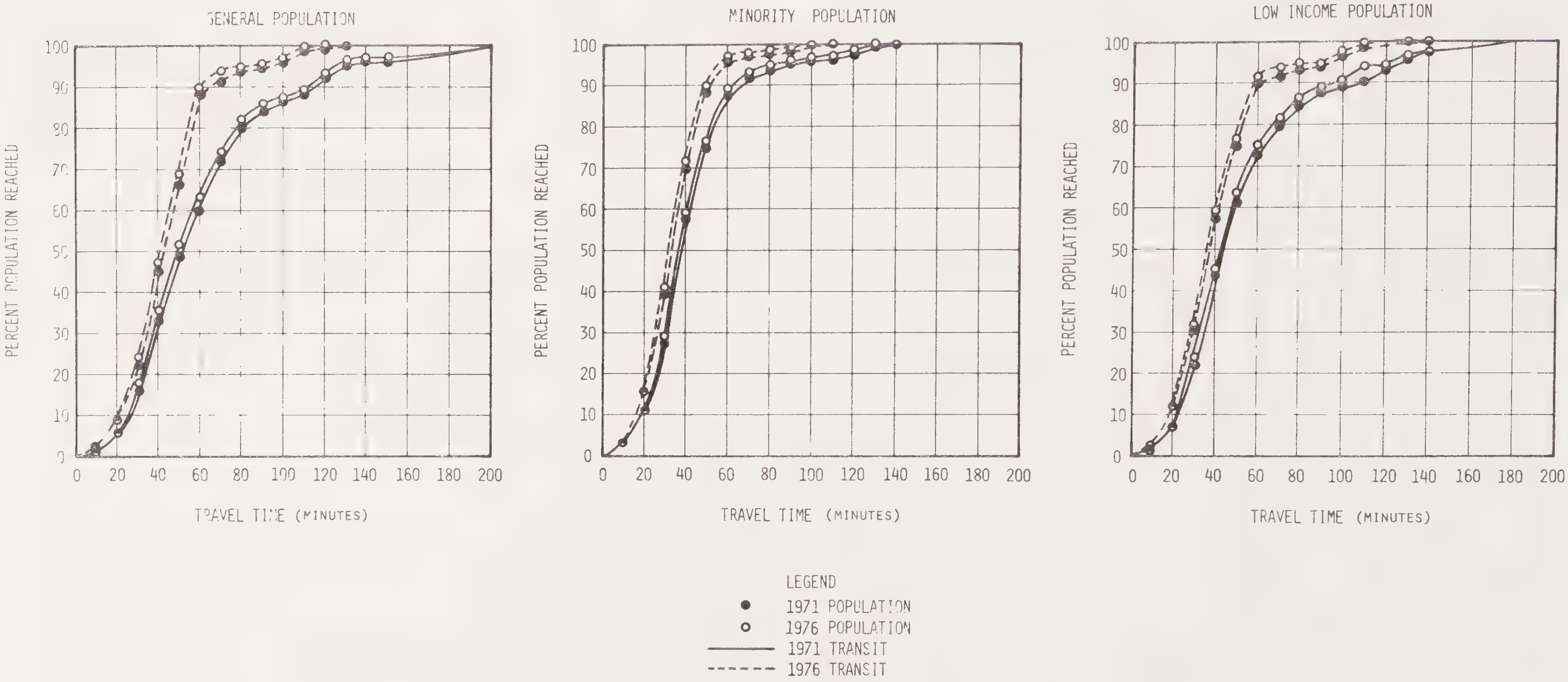

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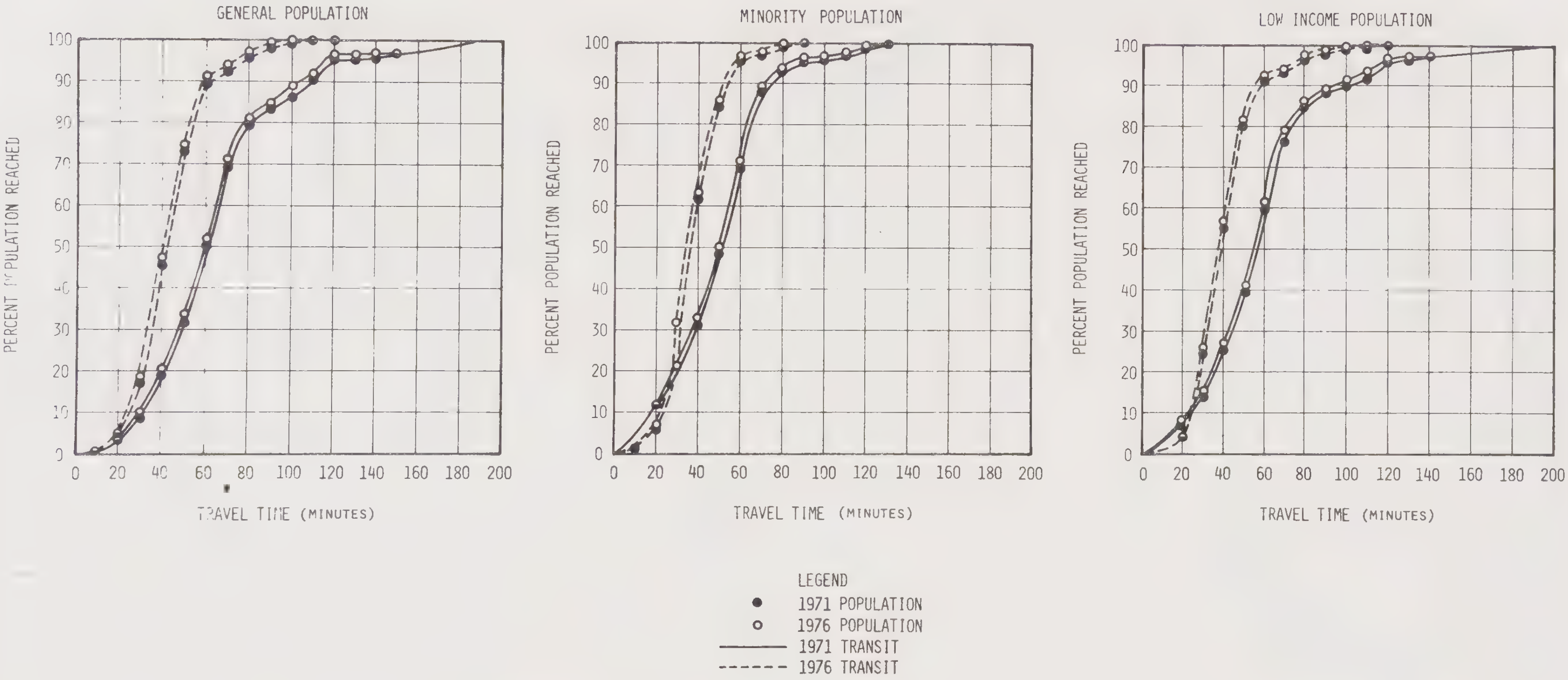

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APPENDIX C

RATIONALE AND SPECIFICATION FOR THE NO-BART ALTERNATIVE

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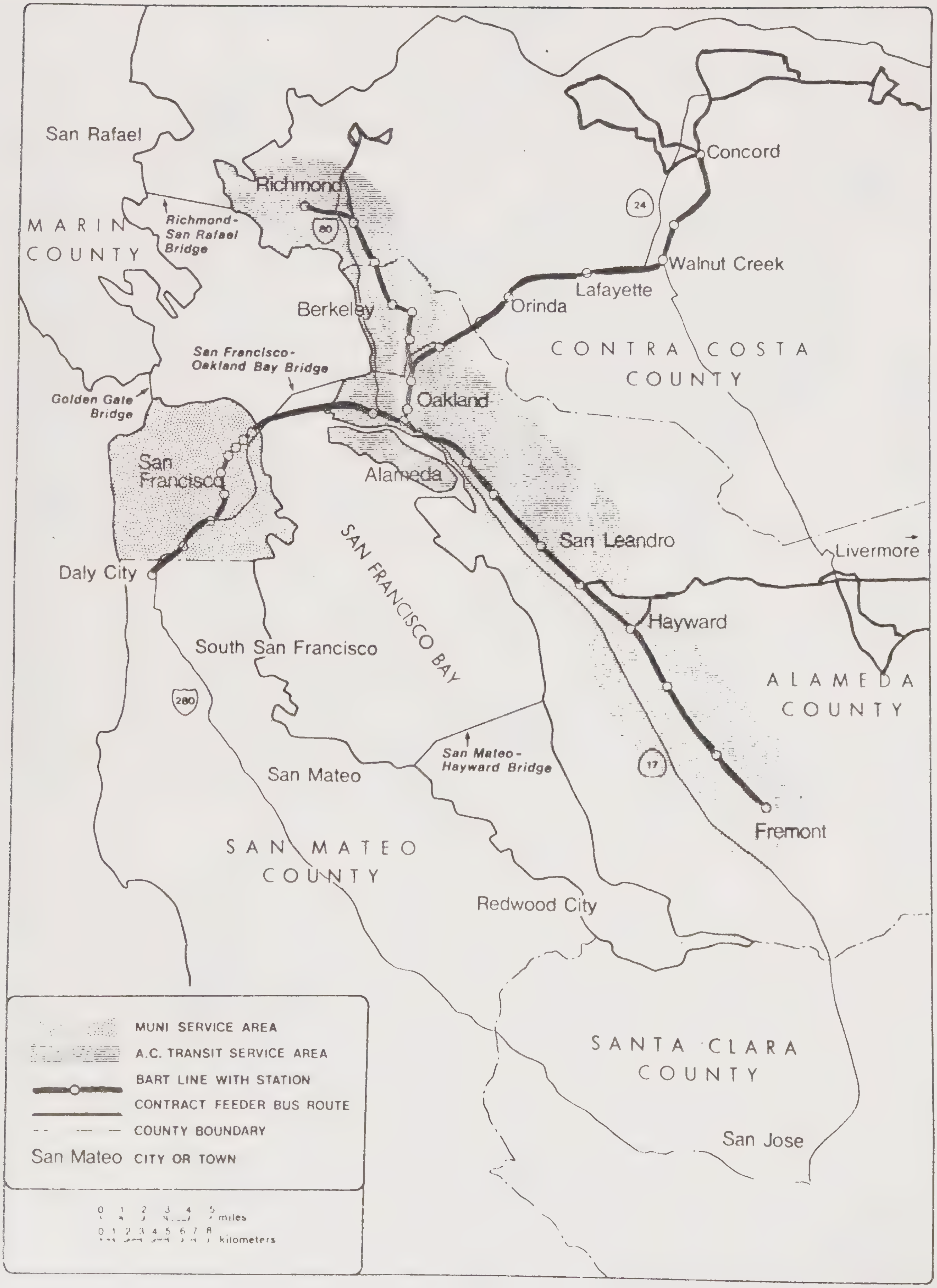

San Rafael
MARIN COUNTY
Richmond
Richmond-San Rafael Bridge
80
24
Concord
Walnut Creek
Lafayette
Orinda
Berkeley
CONTRA COSTA COUNTY
San Francisco-Oakland Bay Bridge
Golden Gate Bridge
Oakland
San Francisco
Alameda
SAN FRANCISCO BAY
San Leandro
Livermore
Daly City
Hayward
South San Francisco
ALAMEDA COUNTY
280
San Mateo-Hayward Bridge
17
San Mateo
Fremont
SAN MATEO COUNTY
Redwood City
SANTA CLARA COUNTY
San Jose
MUNI SERVICE AREA
A.C. TRANSIT SERVICE AREA
BART LINE WITH STATION
CONTRACT FEEDER BUS ROUTE
COUNTY BOUNDARY
San Mateo CITY OR TOWN
0 1 2 3 4 5 miles
0 1 2 3 4 5 6 7 8 kilometers

INTRODUCTION

MTC has defined the No-BART Alternative (NBA) as the transportation system judged most likely to have evolved in the central Bay Area by 1976 had the decision to build BART not been made in 1962. Rather than a strictly hypothetical alternative, the NBA is one of the basic analytical tools used in the BART Impact Program to isolate BART's effects from other unrelated though concurrent changes in travel, land use, the economy and institutions of the Bay Area. While the NBA is not the only method used for controlling for these external effects, it is the only control that is to be used as a common point for comparison by all six major projects of the Impact Program. Therefore, it is necessary to define the NBA in a consistent manner for use by researchers in the Program and for better understanding of the Program's methods and findings by its audiences. This document is intended to serve those purposes.

Following this introduction is a brief summary of key points about the NBA. More detail is provided in Part I, following the summary. The role of the NBA in the Impact Program is reviewed, followed by the description of how it was defined and how it will be used, concluding with the limitations for use of the NBA. Part II contains documentation of how the NBA transportation system networks were defined.

The MTC travel demand models are not yet ready to be run using the NBA networks. If the model forecasts later show an unreasonable level of automobile congestion or transit vehicle crowding, the NBA definition will be reviewed and modifications will be made in an addendum to this Working Note.

THE NO-BART ALTERNATIVE: SUMMARY

What is Meant by the "No-BART Alternative"?

The No-BART Alternative (NBA) has been defined as the transportation system judged most likely to have evolved in the central Bay Area by 1976 had the decision to build BART not been made in 1962.

Why is the NBA Needed?

The NBA is one of the basic analytical tools in the BART Impact Program for isolating the net effects of BART from those changes in travel patterns and behavior, the economy, environment and institutions of the Bay Area which were due to factors other than BART.

How was the NBA Defined?

An analysis was made of the political and financial environment in the Bay Area at the time of the BART decision and in the following years in order to determine the most likely components of the NBA. These components were further reviewed in the context of actual 1976 travel demand and 1971-76 trends in the BART corridors to ensure that the level of service provided by the NBA was plausible.

How Will the NBA be Used in BIP Projects?

The Transportation System and Travel Behavior (TSTB) Project will use computerized representations of the NBA, pre-BART (1971) and with-BART (1976) transportation systems ("networks") to: (1) assess the changes in accessibility due to BART, and (2) use a set of mathematical models of travel demand to estimate transit patronage, auto/transit modal split, traffic congestion, costs and revenues of transportation, and vehicle use. The other BIP projects will make use of the TSTB accessibility and travel model comparisons either generally as background for their findings (e.g., Public Policy, Institutions & Life Styles), or more specifically as directly affecting other kinds of impacts (e.g., Land Use & Urban Development, Economics & Finance, Environment).

What Are the Principal Components of the NBA?

The NBA includes all freeways and principal local streets which exist in 1976, but no additional highway facilities.

There are relatively minor changes in the operations of the major transit services in the central Bay Area from the 1971 pre-BART base to the 1976 NBA. 1973 was found to be a peak year for provision of transit service by Greyhound (commuter buses from central Contra Costa County to downtown Oakland and San Francisco) and AC Transit (transbay commuter buses). Small improvements in frequencies in the San Francisco Muni's routes in the Mission corridor were made, but no new routes were introduced.

One major difference between the NBA and with-BART transportation systems is the provision of transbay transit service by BART throughout the midday off-peak period, while the NBA contains little or no such service.

What are the Assumptions and Limitations of the NBA?

Given the limitations in the analytical and theoretical state-of-the-art to forecast the future, the NBA is defined only as a transportation system alternative. It thus assumes no changes in the population, employment and land use distributions from the actual case in 1976. There are inherent limitations to the amount of detail possible in the NBA description, given this single-minded definition. For example, while TSTB will be able to estimate travel demand and accessibility with some detail, the local NBA zoning policies will have to be more judgmental and generalized in the Public Policy Project. The effects of the NBA therefore cannot be as thoroughly measured as those in the with-BART world. Each project will establish the most appropriate role for NBA comparisons consistent with these limitations.

THE NO-BART ALTERNATIVE: PART I - BACKGROUND FOR THE NBA

The Role of the NBA in the BART Impact Program

The principal goal of the BART Impact Program is to accurately measure the direct and indirect effects of BART's construction and operation upon the Bay Area's people, envirnoment, economy and institutions. In order to measure impacts, however, it is essential to establish the appropriate basis for comparison. There are several methods for making these comparisons, and all are used in varying degrees in all the BIP projects. The basic methods are:

(1) Before/After

Data representing conditions immediately before and after the construction or operation of BART can be compared and the difference between them judged a "BART Impact". This method is appropriate for some impact measurements which have a well-defined time-scale and scope of impact.

(2) Trend Line

A more generalized case of before/after comparisons, a longitudinal data series ("trend line") established well before any expected BART impacts could show deviations from an historic trend after the introduction of BART. While this allows the use of some statistical tests, it still relies on a rather well-defined "event" to separate the "before" data from the "after".

(3) Control Group

Related to the classical experimental design is the use of population groups or geographic areas similar in all significant ways except for the presence or absence of BART. Comparisons between groups can be made using either before/after or trend line data and the difference between the groups attributed to BART. The principal difficulty in this method is that it is rarely possible to find control groups (non-BART) which satisfy all theoretical demands for similarity with the experimental group (with BART).

(4) Alternatives

Measurements of "with-BART" (post-BART) conditions may be compared with the estimated or projected data for one or more non-BART alternative transportation systems. Measured data are compared with projections based upon some cause-and-effect models, or with estimates based on professional judgment or informed opinions. The basic limitation of comparisons with

alternatives is the difficulty in establishing a convincing foundation for the projections or estimates. The shortcomings of existing land use/transportation/urban development theory are well known, and thus projections or estimates based upon them may always be subject to severe scrutiny.

The use of before/after, trend line and control group comparisons is documented in each impact project's Research Plan or Study Design based upon each one's internal needs for consistency and the overall integrity of their research strategies. Each type of comparison has important theoretical and practical limitations alluded to above. The resolution of these difficulties is left to each project, which is best aware of the research needs and data limitations in its area. The alternatives comparison, however, was identified as a key unifying element in the overall analytical scheme of the BART Impact Program and therefore was developed by MTC to be uniform for all projects. Nonetheless, the essential nature of the chosen alternative, the NBA, is similar in purpose to the other three types of comparison. It is intended to supplement the other impact analysis methods, to reduce dependence upon any single, limited approach, and to support final conclusions about BART's net effects.

The next section describes why the choice of the "most likely" alternative was made, rather than other hypothetical choices.

The Choice of the "Most Likely" Alternative

There are several possible alternative systems for comparison with BART. MTC's decision to pursue only the most likely alternative at this point in the Impact Program was based on two criteria: reasonableness and relevance.

Under the first criterion of reasonableness, we had to reject purely hypothetical alternatives like automated fixed guideways. Instead, we focused upon those transportation systems which had been implemented in American metropolitan areas within the span of BART's history (1956-76). These included emphasis on highways, exclusive bus lanes on highways or separate rights-of-way, automated control of traffic on highways, bus priority ramp metering systems for congested freeways, or combinations of these elements. Also included in the list of reasonable systems was the "do-nothing" or "no-build" alternative common in environmental impact analyses.

The choice of the one most likely among these reasonable alternatives was then based upon the relevance of the alternative to the primary goal of the BART Impact Program: the accurate measurement of BART's impacts. The basic analytical need to serve this goal is to isolate the impacts due to BART from those due to other factors or from those which would have happened with or without BART. To fill this need, an alternative must be not only technically, politically and financially reasonable, but also likely to

have occurred in the context of the Bay Area. The method for narrowing the list of what could have happened to what probably would have happened is described in the following section.

It should be clear that this choice of a most likely alternative precludes several interesting types of comparisons. It will not allow comparisons based upon:

(1) a level of expenditure equal to BART's;

(2) a level of transit service equivalent to BART's;

(3) the best financially or technically conceivable alternative; or

(4) goals of immediate importance to current decision-making.

MTC recognizes the need to pursue comparisons of these types and will consider them in later stages of the BART Impact Program. These "alternatives analyses" would be similar to those conducted in traditional transportation planning studies and within the recent UMTA capital grant guidelines. However, the most pressing need at this time is to support each project's accurate assessment of BART's impacts. The most likely alternative, along with the other BIP research strategies, will provide this base.

The Definition of the NBA

In order to define the most likely alternative to the with-BART transportation system, MTC retained a consultant to review and document both the history surrounding the key decisions that led to construction of BART, and to make an evaluation of the political and financial environment in the Bay Area that would have shaped an alternative transportation system had the BART bond vote failed. The two reports(1) led to the conclusion that improvements in the region's transportation system would have been on an incremental basis without BART, with no major new highway facilities constructed and no major new transit services introduced. While somewhat surprising to some, MTC considered this conclusion reasonable, based upon two observations. First, the decision to build BART was not a choice among competing comprehensive regional transportation plans, but a single-minded determination to plan, fund and build a rail rapid transit system. Thus there was no "option #2" to be brought forward if the bond vote had failed. Second, a review of experience in other metropolitan areas confirmed that when a transit bond issue failed, there was no predictable effect upon the level of highway construction. In other words, there was no direct substitution of highway proposals for transit, primarily due to the very different funding mechanisms.

(1) "The Generalized No-BART Alternative Transportation System" McDonald & Smart, Inc., May, 1975, FR 1-14-75

"A History of the Key Decisions in the Development of Bay Area Rapid Transit" McDonald & Smart, Inc., September, 1975, FR 3-14-75

The determination of the most likely alternative involved personal interviews with key decision-makers, reviews of availability of funds for transportation investments, evaluation of political interests, and an historical perspective on trends in urbanization and travel demand in the Bay Area. These all supported the same general conclusion of incremental improvements in transportation. This consensus lends credence to the choice. Though "hypothetical", the chosen NBA is not based on mere conjecture, no better than anyone's guess. It rather represents in a straightforward and defensible manner the logical conclusions of a detailed analysis of factors affecting transportation decisions in the Bay Area.

Use of the NBA in Each BIP Project: Expectations and Limitations

It is important to reiterate that the NBA is an alternative transportation system, and not an alternative scheme for urban development, regional economics, social dynamics or institutional relationships. This is justifiable from three points of view:

(1) We have defined our interest as affecting transportation decision-making. In few cases are metropolitan areas blessed (or burdened) with a single governmental unit which makes all decisions on transportation, housing, land use and all other public investments. Even if this were the case somewhere, it is not so in the Bay Area, and therefore we can offer no practical information on how such global decisions could be made. Our interest must therefore be confined to an alternative transportation investment, and the effects that flow from that decision.

(2) The planning tools for forecasting population, housing employment and travel demand are all suspect to some degree, and thereby always limit the credibility of any effort to look into the future. However, of these, the travel models appear to be among the most accepted planning tools, and certainly encompass the greatest experience of planners and modelers. Therefore, we choose to develop the NBA as a transportation system in terms suitable for use by the only future-forecasting tool in which we have any confidence.

(3) For the most part, hypothesized BART impacts flow from characteristics of BART as a provider of transportation services. There are exceptions, like the direct physical environmental impacts of BART structures on their surroundings and the effects of BART's funding upon regional financing and bonding capacity. However, all other major kinds of impacts are secondary effects of people riding or not riding the trains, or of their potential for doing so. Thus the transportation impacts of the NBA are, by design, central to BIP analyses.

With this in mind, it is fairly simple to define how each one of the BIP projects will utilize the NBA. The central analyses will be accomplished by TSTB in establishing the NBA and with-BART networks, developing accessibility measurements comparing the two networks, and producing estimates of travel demand using the set of models now being developed by MTC. In building the networks and running the models, several outputs are either direct measures of differences between BART and the NBA or are inputs to analysis of secondary impacts. The principal relationships are as follows:

(1) Accessibility measures are used by

   a. TSTB as direct comparisons of travel potential for major types of trips and markets

   b. Land Use as indications of where pressure for land development or property value changes might be most or least likely

   c. Economics & Finance to establish where any changes occur in the match between worker residences and jobs.

(2) Travel forecasts produce:

   a. volume of travel by mode, which is used by

      - TSTB as a direct comparison of transit/auto share

      - TSTB for congestion and level-of-service comparisons

      - Environment for comparison of noise and air quality impacts

   b. costs of travel which are used by

      - TSTB as direct comparison for certain types of trips

      - Economics & Finance for comparing transit revenue.

These relationships are already defined in the context of the overall BIP conceptual framework of causation and within each project's Research Plan. However, other relationships are expected to be established during the course of individual projects and will be pursued at that time. For example, as yet there is only a hypothesized connection between transportation system level-of-service and family life styles. As the study of life styles uncovers the dimensions to that relationship (what kinds of service affect what kinds of people), comparisons with the NBA may be suggested, even though not immediately evident at the outset. In general, the most informative NBA comparisons will be made only

when all projects have firmly established the cause-effect relationships between transportation system characteristics and their individual areas of interest. They then can turn to the NBA/BART accessibility and travel model comparisons to see if significant differences occur along their particular dimensions of interest.

Beyond the relationships listed above, the basic constraint on NBA use is therefore established:

> Each BIP project can only expect to perform BART/NBA comparisons for their own identified cause-effect relationships, and for which the dimensions of the relationships are already incorporated in accessibility measures and in the structure of the forecasting models.

This is an important point, and one which will save unneeded agonizing over detailing each and every connection between the NBA and the individual projects.

To restate the point another way, the limits to use of the NBA by each project are inherent in its definition as a transportation system and in the analysis of that system by only the established tools of travel models and accessibility measures. When each project reaches that point where it has firmly established the link between BART and the transportation system on one hand, and its own area of interest on the other (e.g., land use or life styles), only then will it <u>know</u> what to look for in the NBA comparisons. Furthermore, it can <u>only</u> make those comparisons which the tools are capable of producing. Therefore, there is <u>no</u> need to pre-specify the shape each NBA comparison will take. The best specifications for the comparisons in each project will come later, and when they do, the <u>only</u> NBA data that will be <u>possible</u> will already be available or will be easily accessible.

This argument will leave some kinds of NBA comparisons to the judgment of the individual project consultants when they are not able to link impacts directly to transportation system characteristics. This must be accepted as a natural limitation on the possible level of detail in NBA analyses. Particularly in the area of social and economic analyses, each project will have to make the best possible use of the TSTB-based NBA comparisons, and draw whatever other inferences it can from its own analyses. In accepting these limitations we recognize that each project cannot and need not use the NBA in precisely the same way.

<u>Assumption Within the NBA</u>

With the NBA confined to a transportation system definition, all other possible variables are held constant. In comparing the NBA with the with-BART world of 1976 we therefore assume the following:

(1) The general pattern of urban development is unchanged. Since BART was designed to serve the pattern established by automobile-encouraged suburbanization in the post-World War II period, it is firmly embedded in historically and topographically determined corridors. The assumption therefore seems reasonable.

(2) The population, housing and employment totals (not necessarily their distribution) for the region are unchanged. Major changes would have had to have been due to national economic or political factors assumed unaffected by BART. The short-term effect of BART on local construction employment is examined as a special analysis in the Economics & Finance Project, and is therefore not part of the NBA comparisons.

(3) Bay Area institutions dealing with transportation would be unchanged. With the repeated failure over two decades to establish a multiple-purpose regional government, and with the continued dependence of local transit upon taxpayers within defined jurisdictions, no regional transportation agency could be assumed to have developed from the NBA.

General Conclusions

The inherent limitations of NBA analyses have already been described in the previous section on "Use of the NBA". There had been some unfortunately grandiose statements in prior stages of the BART Impact Program that the NBA analyses would be the cornerstone for all final statements about BART's impacts and implications for policy choices in the future. This is simply not the case, and was a thoroughly unrealistic goal from its inception. The NBA analyses, like all the other methods of detecting impacts and drawing comparisons, are but a different type of methodological weapon in our arsenal, complementing but not substituting for any of the others.

A recent NCHRP report, The No-Build Alternative: Social, Economic and Environmental Consequences of Not Constructing Transportation Facilities,[1] confirms our suspicions. A survey of transportation planning agencies concludes that the technical adequacy of impact prediction methodologies is distrusted for all but direct transportation impacts and direct environmental impacts of physical structures. We are simply adopting the conservative approach of not extending our analyses past our known abilities. To attempt an evaluation of the full economic and social impacts of the NBA would be at best presumptuous and at worst ludicrous. We recognize and accept its limitations, and therefore want to keep it in this proper, overall Program perspective.

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[1] National Cooperative Highway Research Program, Transportation Research Board, Project 8-11, 1975, by David A. Crane & Partners, Inc., et. al.

THE NO-BART ALTERNATIVE:
PART II - SPECIFICATION OF THE NBA NETWORKS

Characteristics of a System Definition

Since the GNBA assumed no major new highways, the system changes described below concern only transit components. In order to describe its level-of-service for network development purposes, the following six characteristics were identified for each component:

(1) The Route Location

The route location defines precisely what roadway facilities will be utilized by the route and implicitly delineates a patronage "shed" and helps to define for a geographical unit its accessibility in conjunction with all other routes serving that area. This accessibility can be illustrated in terms of the number of residents within reach of transit service, the number of route miles/per square mile, or even possibly as indications of the cost and revenue sharing distribution for a transit system.

(2) The Operating Company

The operating company determines a number of significant operating values, including:

- the fare assessment structure
- the type of transport equipment
- the mechanics of implementation to network representation (mode, line, etc.)

(3) The Operating Speed Over Each Segment of the Route

The operating speed is the major determinant of in-vehicle travel time, one of the most important determinants of modal choice and measures of accessibility.

(4) The Type of Operation (Local, Limited, Express, Etc.)

The type of operation influences both the operating speed and the likely form of travel to utilize the service. For example, work related trips are more likely to be attracted to higher speed express service, as the commute trip is normally a longer trip and values time saving more highly.

(5) Hours of Operation (Peak, Off-Peak)

The hours of operation, whether peak or off-peak, are determinants of both the type of operation and directly influence the cost of that operation.

(6) Frequency of Service for Each Time Period

The frequency of service is among the most critical variables describing the level-of-service. The wait/transfer time associated with a transit route is a major determinant of its potential usage and likewise its capacity. It greatly influences equipment requirements and the cost of operation. Balancing this supply level with resulting demand (usage) is fundamental to system efficiency.

NBA Components

This section discusses each of the NBA components, the process followed in describing its level-of-service characteristics, and the results of this quantitative analysis. In all cases the interpretation of a component was based upon the intent of the GNBA description and its perspective on the prevailing institutional framework. In many cases, specific quantitative data were utilized to ascertain the extent of system improvements beyond the pre-BART (1971) period.

The four components of the NBA comprise all major public transit operators in the three BART counties, the San Francisco Municipal Railway (MUNI), which operates diesel and trolley buses, streetcars and cable cars in the city and county of San Francisco; the Alameda-Contra Costs Transit District (AC), which operates buses in the densely urbanized areas of Alameda and Contra Costa Counties; and Greyhound lines, which provides commuter express service from outlying areas of Contra Costa and San Mateo Counties to downtown Oakland and San Francisco.

A. Upgrading of the MUNI Transit System

In general, the majority of improvements which have occurred in the MUNI transit system since 1971 have been primarily the replacement of aging vehicles and other related equipment. Little change has occurred in the route structure or frequency of service provided by a majority of the MUNI routes.[1] The GNBA research has suggested further that this general upgrading has occurred relatively independently of the decision to construct and operate BART. The existing service prior to BART provided good access to most areas of the city with an excellent scheduled frequency of service. Because of these existing characteristics

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(1) "The Generalized No-BART Alternative Transportation System" McDonald & Smart, Inc., May, 1975, FR 1-14-75

MUNI's planning for future improvements was very much on a short-term, incremental basis, specifically aimed at improving the comfort and reliability of service.

The research did however suggest two areas of improvement which might have been pursued by MUNI in the absence of BART. First it suggested that improved frequencies of service in both the Mission Street and Balboa Park/Glen Park areas might be necessary to service the relatively long-distance work-commute trip to downtown San Francisco. And secondly, that MUNI might have considered providing Express Bus Service possibly on preferential freeway lanes from the southeastern and southwestern areas of the city. A three-step analysis was used to define and quantify this NBA component.

It was necessary first to describe and map the pre-BART (1971) service in both the Mission Street and Balboa Park/Gen Park areas. Any changes (improvements) made to the MUNI system in those areas would have to be based upon the existing (1971) pattern of routes and their individual frequencies of service.

Because the service in both these areas of San Francisco was at a relatively high level, and without detailed patronage data, it is difficult to speculate on the ability of the existing (1971) service to accommodate an increased level of travel demand in 1976. Assuming first that the existing service was operating at maximum load factors in the pre-BART period (or full utilization of available capacity), an analysis was made of current BART patronage data in order to calculate the maximum amount of additional service that might be required. A summary of patronage for each of the BART stations (with 16th and 24th Mission stations summarized in combination) in these two areas is presented in Tables 1-3.

The potential additional bus requirement was calculated by assuming an average capacity of 40 passengers per vehicle.[1] For example, the 16th and 24th Street Mission BART stations in January, 1976 were carrying approximately 592 passengers to downtown San Francisco in the a.m. peak hour. Dividing this by the assumed 40 passengers per vehicle results in a potential requirement of 15 additional buses in the peak hour. (It should be noted that 15 buses/hour is measured at the maximum patronage load point, and therefore, the actual fleet size might be either less or greater than 15 buses, depending upon the length and speed characteristics of the route.)

However, it is reasonable to assume that neither the existing (1971) service was operating at full capacity nor would all the existing 1976 BART patronage be diverted onto the MUNI system (i.e. many patrons would have continued to use the automobile from the pre-BART period). This became quite evident from review of the 1975

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(1) Based upon MTC transit vehicle occupancy data on selected MUNI routes in April, 1973 (prior to BART operations in San Francisco).

TABLE 1

16TH & 24TH STREET MISSION BART STATIONS

PATRONAGE MOVEMENTS

STATION	AM PEAK HOUR ORIGIN	AM PEAK HOUR DESTINATION	MAXIMUM OFF-PEAK HOUR ORIGIN	MAXIMUM OFF-PEAK HOUR DESTINATION	DAILY ORIGIN	DAILY DESTINATION
Civic Center	8	51	24	25	332	317
Powell Street	19	101	66	60	865	713
Montgomery	10	440	38	52	1,122	1,199
	37	592	128	137	2,319	2,229
Glen Park	18	2	7	8	97	110
Balboa Park	14	22	11	9	163	191
Daly City	49	15	17	17	331	338
	81	39	35	34	591	639
*R-Line	13	24	14	25	258	285
K-Line	23	55	11	9	256	278
A-Line	46	27	18	17	386	385
C-Line	43	10	6	10	240	276
TOTAL EAST BAY	125	116	49	61	1,140	1,224

* The R-Line is defined as that segment including the Richmond, El Cerrito Del Norte, El Cerrito Plaza, North Berkeley, Berkeley and Ashby Stations. The K-Line segment is composed of the 12th Street and 19th Street Oakland Stations, MacArthur, and Oakland West Stations. The A-Line segment is composed of the Lake Merritt, Fruitvale, Coliseum, San Leandro, Bay Fair, Hayward, South Hayward, Union City, and Fremont Stations. The C-Line segment is composed of the Rockridge, Orinda, Lafayette, Walnut Creek, Pleasant Hill, and Concord Stations.

TABLE 2

BALBOA PARK STATION

PATRONAGE MOVEMENTS

STATION	AM PEAK HOUR ORIGIN	AM PEAK HOUR DESTINATION	MAXIMUM OFF-PEAK HOUR ORIGIN	MAXIMUM OFF-PEAK HOUR DESTINATION	DAILY ORIGIN	DAILY DESTINATION
Civic Center	28	116	25	26	505	466
Powell Street	56	73	44	52	846	705
Montgomery	18	454	24	36	1,299	1,406
	102	643	93	114	2,650	2,577
16th/Mission	7	13	5	5	99	92
24th/Mission	11	5	4	6	92	71
	18	18	9	11	191	163
Daly City	17	1	3	5	65	66
R-Line	6	11	6	7	96	104
K-Line	6	11	3	6	80	83
A-Line	16	11	6	4	108	112
C-Line	18	1	3	2	76	75
TOTAL EAST BAY	46	34	18	19	360	374

TABLE 3

GLEN PARK STATION

PATRONAGE MOVEMENTS

STATION	AM PEAK HOUR ORIGIN	AM PEAK HOUR DESTINATION	MAXIMUM OFF-PEAK HOUR ORIGIN	MAXIMUM OFF-PEAK HOUR DESTINATION	DAILY ORIGIN	DAILY DESTINATION
Civic Center	5	114	16	16	390	398
Powell Street	5	155	35	39	819	669
Montgomery	4	637	25	25	1,510	1,592
	14	906	76	80	2,719	2,659
16th/Mission	0	13	4	4	58	55
24th/Mission	2	5	4	3	52	42
	2	18	8	7	110	97
Daly City	7	2	4	8	54	54
R-Line	1	18	6	3	103	96
K-Line	0	30	1	2	78	86
A-Line	6	8	2	2	91	102
C-Line	4	6	2	1	54	61
TOTAL EAST BAY	11	62	11	8	326	345

Passenger Profile Survey data for each of the above four stations (Table 4). Of all patrons interviewed at these stations, approximately 70% had been prior bus passengers (MUNI). This implied that only 30% of the additional service requirement might actually be necessary. Table 5 lists the affected MUNI routes and the assumed increment of service.

Any potential for the use of express bus service on freeways was dismissed primarily based upon the relatively low level of BART patronage currently observed in these two areas, and the relatively high level of existing service. Furthermore, there is no basis upon which to assume that MUNI would have provided service to northern San Mateo county in the absence of BART. It would require a change in the jurisdictional coverage of MUNI which the GNBA points out was highly unlikely. In summary, MUNI service in the NBA differs only slightly from the 1971 pre-BART condition reflected by only a small increment of service improvement in the Mission corridor.

B. Increased Transbay Bus Service

Transbay bus service operated by the AC Transit District is a prominent component of the NBA. The provision of this high-quality, express service from East Bay Communities to San Francisco has historically carried significant numbers of work trip commuters. Summarized in Table 6 is a comparison of mass transit passengers crossing the Bay in the peak hour for the pre-BART (Spring, 1973) and the post-BART (October, 1975) periods. Although BART is now the primary carrier of that peak hour patronage, AC Transbay operations have still continued to serve a significant volume, even with reduced levels-of-service from 1973. The GNBA research has determined that AC Transbay operations would have likely continued beyond 1973 to be the major carrier of transbay transit patronage.

Each (Transbay) route operating in 1971 was traced in order to evaluate the coverage area and frequency of service. Historical count data for this corridor confirm that in 1973 AC provided its maximum amount of Transbay service. Analysis of route schedule information from the Transportation System Inventory quantified that level-of-service by individual route. Table 7 summarizes that comparison.

Similar to the MUNI component, it is difficult to ascertain precisely what a reasonable level of supply might likely be for 1976 without some assumption or measurement of travel demand. Historical Bay Bridge counts have found averages of 40 to 42 passengers per AC vehicle passing through the toll booths.(3) This would allow for some increases in patronage without requiring additional equipment since these vehicles seat between 50-55 passengers. If both the AC Transbay and Western Greyhound service into San Francisco were to operate at 1973 levels and at full capacity (load factor=1) the total passenger carrying

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(3) Ibid.

TABLE 4

1975
BARTD PASSENGER PROFILE SURVEY

SUMMARY OF
PRIOR MODE BY STATION OF ORIGIN

HOME-BASED WORK

PREVIOUS MODE

STATION	NONE	BUS	AUTO	SHARED RIDE	KISS/ RIDE	CYCLE	BIKE	WALK	OTHER	TOTAL
Balboa Park	19	116	30	15	7	-	-	1	3	191
Glen Park	43	142	32	13	5	2	-	2	1	240
16th/Mission	31	76	21	1	5	1	-	9	2	146
24th/Mission	30	112	23	3	4	-	-	4	-	176

TABLE 5

CHANGES IN MUNI ROUTE FREQUENCIES

MUNI ROUTE NUMBER		ROUTE NAME	PRE-BART (1971) AM HEADWAY (MIN)	ASSUMED NBA AM HEADWAY (MIN)	NBA BUS FLEET ADDITIONS
9	(16)	Richland	8.8	6.7	2
11	(18)	Hoffman	9.2	7.5	2
15*	(24)	Kearny	30.0	15.0	2
25*	(59)	Valencia	12.0	6.0	6
K*	(130)	Ingleside	3.7	3.2	4
					16

* These MUNI routes are represented in the computerized network by more than one network line in order to reflect cutbacks, extensions, or variations in the service or the service route. In making network modifications only one line from the total route representation was chosen, therefore, interpretation of the headway shown as the composite level-of-service for a route is misleading.

TABLE 6

TRANSBAY MASS TRANSIT PASSENGERS

COMPARISON OF PEAK-HOUR WESTBOUND
PRE-BART AND POST-BART PATRONAGE

DATE	AC TRANSIT	WESTERN GREYHOUND	BART	TOTAL
April 1973	10,124	3,920	-	14,026*
October 1975	7,636	895	7,730	16,064
Difference	2,488	3,025	7,730	2,038

SOURCE: University of California, Institute of Transportation Studies, Traffic Survey Series, A-40, A-45.

* Because the peak hour varies between individual transit carriers, peak hour patronage totals will differ from individual component values.

TABLE 7

AC TRANSIT
ACTUAL
TRANSBAY SERVICE COMPARISON

ROUTE	NETWORK LINE NUMBER(S)[1]	HEADWAY (MINUTES)[3] 1971 PEAK	1971 OFF-PEAK	1973 PEAK	1973 OFF-PEAK
A1	15,16	30.0	30.0	15.0	18.0
A2	17,18	30.0	30.0	20.0	20.0
B	19,20	15.0	30.0	12.0	20.0
BX	21	10.0	—	10.0	—
B[2]	23	30.0	—	20.0	—
C	24,25	12.0	30.0	7.5	19.0
CH	26	8.6	—	5.0	—
CB	27	15.0	—	10.0	—
C	28	30.0	—	15.0	—
E	29,30	14.7	30.0	12.0	18.0
EX	31	7.5	—	6.5	—
F	32	17.5	—	12.0	10.0
FXX	35	5.5	—	5.0	—
FX	36,37	12.0	12.0	8.5	—
G	39	30.0	—	20.0	—
GX	40	15.0	—	10.0	—
H	42,43,44	60.0	—	20.0	—
HX	45	12.0	—	7.5	—
HX	46	15.0	—	7.5	—

ROUTE	NETWORK LINE NUMBER(S) (1)	HEADWAY (MINUTES) 1971 PEAK	OFF-PEAK	1973 PEAK	OFF-PEAK
K	48,49	30.0	30.0	20.0	17.0
KH	50	8.6	—	8.5	—
SK	51	6.7	—	6.0	—
L	52-56	6.0	—	6.0	—
L1A	57	15.0	—	10.0	—
L1B	58	15.0	—	10.0	—
L2A	59	20.0	—	20.0	—
L2B	60	12.0	—	12.0	—
LX	61	8.6	—	6.0	—
N	63-64	20.0	30.0	20.0	14.5
NH	65	7.5	—	7.5	—
NX	66-67				
O	69-70	30.0	42.6	15.0	23.0
O	72	20.0	—	10.0	—
OX	71	8.6	—	8.6	—
OX	73	8.6	—	8.6	—
RD	74	7.5	—	8.6	—
RCV	75	8.5	—	8.6	—
RH, RF	76-79	6.6	—	6.6	—
S	80	10.0	—	6.0	—
SW	81	15.0	—	12.0	—
T	82-83	20.0	60.0	20.0	30.0
T	84-85	30.0	50.0	30.0	25.0

ROUTE	NETWORK LINE NUMBER(S) (1)	HEADWAY (MINUTES) 1971 PEAK	OFF-PEAK	1973 PEAK	OFF-PEAK
V	86	20.0	—	20.0	—
V	87	12.0	—	7.5	—
W	88	12.0	—	12.0	—
W1	89	30.0	—	27.0	—
W1	90	15.0	—	8.5	—

[1] Network Line numbers correspond to routes located in mode 6 of the R711 Network

[2] Many routes offer variations (cutbacks, extensions, headway) which are reflected by coding each individual variation

[3] Headways defined for network implementation may differ somewhat from actual route schedules. A description of the network development process explaining these differences can be found elsewhere.

capacity would be approximately 17,500 in the peak hour. This capability exceeds the transit total person movement observed in 1975 (16,064). It would be unrealistic therefore to increase the Transbay level-of-service beyond 1973 levels, as it can safely be assumed that AC would be more likely to respond with improved frequency levels on existing routes rather than provide additional or new service for potentially marginally gains in ridership. In summary, AC Transbay service in the NBA differs from the 1971 pre-BART condition in that service frequencies are substantially improved on most routes, but is similar in the respect that Transbay service would continue to be oriented to the peak hour commuter.

C. East Bay Express Bus Service

Generally, AC provides three types of bus service in the East Bay:

- local feeder/collection/distribution
- inter-area express
- transbay local and express

Local service will be discussed in a subsequent section and Transbay bus service was described previously. AC East Bay express service provides limited-stop and/or bus on freeway operation. They are primarly oriented in a north/south fashion, connecting cities such as Richmond and Hayward with Oakland and Berkeley. Although BART provides very similar service to the East Bay, AC has not substantially modified or reduced the level of this service from the pre-BART period (1971). With the relatively constant level-of-service to date, it is doubtful AC would have considered substantial increases (or decreases) in this operation considering their other priorities (local, transbay). In summary, no changes in the East Bay Express service from 1971 was assumed for the NBA.

D. Increased Regional Bus Service in Contra Costa County

The type and level of transit service for Contra Costa County in the NBA is substantially different from what operates today. As a result of BART, Greyhound, which previously served that area, has almost entirely discontinued its service.

An analysis similar to that for AC was made to compare the trend in Western Greyhound service and to identify a maximum level (year or period). Table 8 summarizes this analysis for each of the Contra Costs County routes.

Once again, review of count data, in this case for the Caldecott Tunnel which is the entry point to the service area, was made to estimate the likely level of travel demand Greyhound might serve in 1976. Table 9 presents comparisons of the pre- and post-BART periods for this location. It appears that substantial growth

TABLE 8

WESTERN GREYHOUND

CONTRA COSTA COUNTY COMMUTER SERVICE

ROUTE	DESCRIPTION	PEAK HEADWAY 1971	1973
		(MINUTES)	
A	Danville-San Francisco	15.0	4.0
F	Orinda-San Francisco	10.0	10.0
O	Concord-Oakland	15.0	7.5
Z	Concord-Oakland	10.0	-
T	Walnut Creek-San Francisco	6.0	4.6
X	Walnut Creek-San Francisco	6.0	6.0
U	Antioch-San Francisco	60.0	18.0
V	Antioch-San Francisco	29.0	-
Y	Concord-San Francisco	2.0	2.0
R	Concord-San Francisco	3.6	3.6

TABLE 9

CALDECOTT TUNNEL MASS TRANSIT PASSENGERS

COMPARISON OF PEAK-HOUR WESTBOUND
PRE-BART AND POST-BART PATRONAGE

DATE	WESTERN GREYHOUND	BART	TOTAL
Spring 1973	3,895(1)	-	3,895
Spring 1976	845	5,530(3)	6,270(2)

SOURCE: University of California, Institute of Transportation Studies, Traffic Survey Series C-26, C-32.

[1]This estimate was calculated from ITS counts of the number of buses in the peak hour and corresponding occupancy values.

[2]Because the peak hour varies between individual transit carriers, peak hour patronage totals will differ from individual component values.

[3]Based upon seven trains (see text)

in transit patronage has taken place, however, irregular scheduling of BART trains on the survey day, resulted in 7 trains crossing during the peak hour rather than a more normal flow of 5 trains/hour (12 minute frequency). Assuming a BART load factor of 1.2, the capacity for 5 trains would be approximately 3800. Therefore, Greyhound might be expected to potentially serve 3800 passengers in a normal peak but could indeed realize greater demands depending upon the scheduling of their individual routes. The maximum level of Greyhound service in 1973 was 95 buses passing through the tunnel in the peak hour. Depending upon the precise load factor the capacity of this service would range between 3800 and 4700 peak hour passengers.

Once again it is doubtful that Greyhound would have been anxious to improve frequencies with relatively negligible increases in patronage occurring during this period. Therefore, it again seems realistic to assume that the pre-BART (1973) level of Greyhound service would have sufficed for 1976.

Other Characteristics of the NBA

Within the BART service area (counties of Alameda, Contra Costa, and San Francisco) few changes different from the pre-BART period would have likely occurred. The NBA has assumed AC Transit would not have realigned its local routes as it did to serve BART stations, but would instead have continued to operate its pre-BART (1971) routes. The NBA has also assumed the continuation of Greyhound regional trunk service in all other areas of the BART service area. Although they are few in number (Vallejo-Oakland, etc.) they do provide long distance inter-city service.

Within each of the remaining six Bay Area counties the system represented for the NBA is what actually exists in 1976. The most significant change from 1971 pre-BART is the transit system in Marin and Sonoma Counties where Greyhound service was replaced by the Golden Gate Bridge, Highway and Transportation District.

APPENDIX D

COMPARISONS OF TRAVEL TIMES FROM WITH-BART, NO-BART, AND HIGHWAY NETWORKS

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COMPARISONS OF TRAVEL TIMES FROM WITH-BART, NO-BART, AND HIGHWAY NETWORKS

Scope of Analysis

This working note summarizes analyses of zone-to-zone travel times as derived from network representations of the San Francisco Bay Area transportation system. The analyses supplement those presented in two earlier reports of the TSTB Project:

Exploratory Network Analyses of BART's Impacts upon Accessibility, BART Impact Program Working Paper No. WP 15-3-75, July 1975.

"Analysis of BART's Accessibility Impacts," TSTB Project Working Note, December 1976. (unpublished)

The zone system used is the MTC 440 regional traffic zone system defining the 9-county San Francisco Bay region. The analyses summarized in this working note consider only travel times between zones within the 239-zone Greater BART Service Area defined by the three BARTD counties of Alameda, Contra Costa, and San Francisco plus 21 zones in northern San Mateo County. For definition of the zones included in the 239-zone area, see:

"Determination of BART's Service Area," Appendix E, Travel in the BART Service Area, Working Paper WP 35-3-77, October 1977 (Revised).

The analyses focus on (1) peak period travel times from the 239 zones to a set of 50 zones representing the locations of major employment opportunities, and (2) off-peak travel times from the 239 zones to a set of 50 zones representing the locations of major shopping centers.

The top 50 employment zones, listed in the appendix, are the 50 zones in the 239-zone area with the highest 1975 "total employment" as given by ABAG Provisional Series 3 Projections (March 1977).* The top 50 employment zones are shown on the map in Appendix Figure 1 (Parts 1 and 2).

The top 50 shopping zones, also listed in the appendix, are the 50 zones in the 239-zone area with the highest 1975 "local-serving employment" (employment in retail trade, retail services, professional, and other services), again, as given by the Provisional Series 3 Projections. The top 50 shopping zones are shown on the map in Appendix Figure 2 (Parts 1 and 2).

Network Representation of Travel Times

Zone-to-zone travel times are compared for three networks, the "with-BART," "no-BART," and "highway" networks.

* Association of Bay Area Governments

The With-BART Network. This is a representation of the entire 1976 transit system including BART, its bus feeder services, and all other bus and streetcar services in the area. Travel times derived from the network represent travel times between zone centroids via minimum travel time paths through the network. These paths do not necessarily include the use of BART, so with-BART transit travel times from the network are not necessarily estimated travel times using BART itself.

Two versions of the with-BART network are analyzed, one representing morning peak period transit services, and one representing off-peak transit services.

The No-BART Network. This is a representation of a hypothetical 1976 transit system without BART. A general description of the transit services represented by the network is given in "Rationale and Specification for the No-BART Alternative," Appendix C in this report. The network closely represents the bus and streetcar services existing immediately before the start of BART service and reflects judgments about the transit system which would most likely have been in existence in 1976 had the decision to build BART not been made. As is clear from the results given in this working note, the no-BART network represents a transit system providing a much lower level of transit service than the system represented in the with-BART network.

It must be emphasized that the hypothetical no-BART transit network analysed in the working note as the "control" against which BART impacts are assessed is only one of many possible bases for comparison. Clearly, comparison of travel times from the with-BART and times from some different hypothetical no-BART alternative (for example, a system of high-quality express bus services) would give different results.

As with the with-BART network, travel times from the no-BART represent estimates of the time it would take to travel between zone centroids using transit (bus or streetcar). Two versions of the no-BART network are analyzed, one representing morning peak period transit services and one representing off-peak services.

Each transit travel time derived from the with-BART and no-BART networks is the sum of the following estimated time components for travel along the minimum transit travel-time path between two zone centroids: (1) time spent walking or driving to the transit system (BART station, bus, or streetcar stop) from the origin zone centroid, (2) time spent waiting for the transit vehicle (estimated as one-half the average service headway), (3) time spent traveling on the transit vehicle, (4) time spent transferring between vehicles (estimated as one-half the average headway between vehicles of the second and subsequent services), and (5) time spent walking from the transit system to the destination zone centroid. Additional time penalties for transfers are not included in the total travel time estimate. Note, however, that a transfer penalty of four minutes for each transit-to-transit transfer was included in the computations establishing the minimum travel

time paths. This was done to eliminate paths containing an unreasonably large number of transfers.

The zone-to-zone travel time matrices for the transit networks are stored on computer files named as follows:

With-BART Peak Period:	MTC.TRANSIT.R763.AMSKIM1
With-BART Off-Peak:	MTC.TRANSIT.R763.MDSKIM1
No-BART Peak Period:	MTC.TRANSIT.R762.AMSKIM1
No-BART Off-Peak:	MTC.TRANSIT.R762.MDSKIM1

The Highway Network. This represents the 1976 system of streets and highways. Travel times from the network represent estimates of the travel time required to drive between zone centroid locations via the minimum time path in the morning peak period. (No off-peak highway network travel times are analyzed in the report.) The matrix of zone-to-zone travel times is stored on a computer file named MTC.HIGHWAY.R760.UTPS.

Weighted and Unweighted Travel Times

Two kinds of zone-to-zone travel time comparisons are given in the report, unweighted and weighted.

Unweighted average travel times from one zone to many zones (or vice versa) are computed simply by dividing the total number of zone pairs analyzed into the total minutes required for travel between all the zone pairs. For example, in the one-to-many analysis of average travel time from a given residential zone to the top 50 employment zones, the unweighted average represents the total time it would take on average to go from the one residential zone to each of the 50 employment zones. This average travel time is a potential accessibility measure, which, because all 50 zone-to-zone travel times are weighted equally, implies that travel from the one origin zone is equally likely to all 50 possible destinations. The actual pattern of zone-to-zone trip making is not considered. Unweighted travel times were used in the earlier accessibility analyses of the TSTB Project, referenced at the beginning of this report. They are included in the present report for comparative purposes.

To take into account the effects of actual travel patterns, a second set of average travel times is given in the report. These weighted average travel times are computed by weighting the travel time between a given pair of zones by the number of trips made between the zones to give an estimate of trip-minutes spent in travel between the zones. The weighted average travel time, for example for trips between a given residential origin zone and the top 50 employment zones, is then calculated by dividing the total

number of trips made from the origin zone to all 50 destination zones into the total number of trip-minutes for all 50 zone interchanges.

To the extent that the weighted averages take into account actual trip patterns, they may be referred to as "mobility" measures (as distinct from the potential "accessibility" measures provided by the unweighted travel times). As is clear from comparison of the data given in the tables at the end of this working note, the weighted and unweighted average travel time estimates are very different in most cases.

The matrix of zone-to-zone trip interchanges used as the weighting factors are estimates of total 1975 person-trips as stored on a computer file named MTCFCAST.LUUD75.FRATAR.PERS440. Estimates of home-based work trips are used as the weighting factors for the analyses of peak period travel times and estimates of home-based shopping trips are used as the weighting factors for the analyses of off-peak travel times.

Zone-to-Zone Travel Time Comparisons

Three types of analyses and three sets of comparisons are summarized in the tables at the end of the working note.

One-to-Many Analyses. Average travel times are compared for travel between single origin zones (representing selected residential areas) and a set of 50 destination zones (the top 50 employment zones or the top 50 shopping zones).

All-to-Many Analyses. Average travel times are compared for travel between all 239 origin zones in the Greater BART Service Area and the same sets of 50 destination zones.

All-to-One Analyses. Average travel times are compared for travel between all 239 origin zones and single zones (representing selected employment and shopping locations).

With-BART/No-BART Peak Period Comparisons. Tables 1 and 2 compare peak period travel times for the with-BART and no-BART transit networks. Both unweighted average travel times and weighted average travel times are shown, home-based work trips being used as the weighting factors for the latter. Table 1 gives one-to-many comparisons for 17 selected residential origin zones and all-to-many comparisons to the top 50 employment destination zones. Table 2 gives all-to-one comparisons for 13 selected employment destination zones.

With-BART/Highway Peak Period Comparisons. Tables 3 and 4 give the same peak/work comparisons for the same sets of zones as in Tables 1 and 2, respectively, except that data from the with-BART transit and highway networks are compared.

With-BART/No-BART Off-Peak Comparisons. Tables 5 and 6 give with-BART and no-BART comparisons of off-peak travel times using zone-to-zone estimates of home-based shopping trips as the weighting factors. The top 50 shopping zones are the destinations for the one-to-many and all-to-many comparisons.

Caveats

The comparisons shown in Tables 1 through 6 must be interpreted cautiously, for a number of reasons.

Network Travel Time Estimates. Scrutiny of individual zone-to-zone travel time estimates suggests that the networks are generally reasonable representations of actual travel conditions. However, the network estimates are inevitably subject to errors, as suggested by a number of peculiarities and anomalies in the results summarized in this working note. For example, in the peak period between zone 99 (Walnut Creek) and zone 104 (Concord), the with-BART network shows a transit travel time of 28 minutes and the no-BART network a time of 41 minutes, a with-BART advantage of 32%. In contrast, the peak period time from zone 99 to zone 105 (Pleasant Hill), which is adjacent to 104 but closer to 99 than 104, shows a longer with-BART time of 40 minutes and a shorter no-BART time of 31 minutes, a no-BART advantage of 23%. It is also surprising to find the estimate of 99-to-104 with-BART transit travel time (28 minutes) less than the estimated highway time (37 minutes).

Estimates of travel times on "access" links to and from the transit system may be most susceptible to errors. This is suggested by comparison of travel times from adjacent zones for which similar results might be expected. For example, it might be expected that comparison of with-BART and no-BART peak period travel times from any of zones 96 through 105 (defining the Concord-Pleasant Hill-Walnut Creek area) to the top 50 employment zones would give similar results. In fact, the average weighted travel

time differences (no-BART minus with-BART) for travel between each of zones 96 through 105 and the top 50 employment zones show large differences:

Zone	No-BART minus With-BART Travel Time
96	4.3 minutes
98	8.5 minutes
99	11.3 minutes
100	-11.3 minutes
101	-30.3 minutes
102	15.6 minutes
103	22.3 minutes
104	17.8 minutes
105	10.0 minutes

Of course, some of these differences may be accounted for by the peculiarities of the zone system and networks (rather than errors in travel time estimates). In particular, the placement of the zone centroids within zones may be critical. As noted, zones covering very large areas (an average of 2,600 acres for each of the ten zones defining Concord-Pleasant Hill-Walnut Creek) are represented in the network by single locations (the zone centroids). Obviously, how close these centroids happen to be to transit services (for example, Greyhound bus stops and BART stations in the no-BART and with-BART networks, respectively) may have a very large bearing on total transit travel time estimates.

Since the network/zone system is an essentially aggregate representation of transportation facilities and the areas they serve, the results of any network-based analyses are necessarily valid only in an aggregate sense. Comparisons of travel times between individual pairs of zones or small groups of zones must therefore be made extremely warily.

As a means of validating the networks, transit travel times from the with-BART network were compared with travel times reported by respondents to BART ridership surveys. Results of these comparisons are documented in an earlier TSTB Project working note.* The comparisons show generally close correspondence between the network times and the reported times (with the former, if anything, slightly underestimating actual travel times using BART). The comparisons give no reason to suppose any major bias is introduced into the present analysis by the representation of the with-BART transit system.

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*Unpublished working note "Analysis of BART's Accessibility Impacts," December 1976, pp. 67-68. The with-BART transit network analyzed in the December 1976 report (R761) is slightly different from the with-BART network analyzed in the present report (R763). Details of the differences between the two networks have not been investigated, but are small.

On the other hand, it appears that the highway network generally overestimates actual automobile travel times. For example: auto driving time from zone 406 (northwest San Francisco) to zone 422 (downtown San Francisco) is estimated as 25 minutes, only three minutes faster than by transit; auto time from zone 99 (Walnut Creek) to zone 422 is estimated as 64 minutes, 15 minutes slower than by transit; and auto time from zone 203 (Fremont) to zone 422 is shown as 78 minutes, 17 minutes slower than by transit. These automobile travel time estimates seem high; certainly they appear to reflect driving times at times of extreme peak period congestion.

As pointed out, the no-BART network represents a hypothetical transit system, so it can be argued that travel times from the network are, by definition, correct. However, the no-BART network is intended to represent a particular set of transit services (as described in Appendix C, "Rationale and Specification for the No-BART Alternative").

Thus, differences between the transit system as defined in Appendix C and the transit system as represented by the network may fairly be regarded as "errors." (A number of inconsistencies between the no-BART transit system definition and the network representation were commented on in the TSTB Project March 1977 working note "Analysis Plan for Modeling Analyses of BART and No-BART Alternatives," pp. 10-12.) These inconsistencies generally appear to be minor, but their cumulative effect may produce a significant bias in comparisons of the with-BART and no-BART travel times. It seems that again, if anything, this bias overstates the advantages of the with-BART transit system. This is evidenced by the fact that travel times on the no-BART network tend to be higher than travel times on the with-BART network even for travel between zones where one would not expect BART to be used. For example, (unweighted) travel times from zone 406 in the far northwest of San Francisco to 21 other zones in northwestern parts of San Francisco,* none of which one would expect to be affected by BART, are some 5% less on average in the with-BART network than in the no-BART network.

It is extremely difficult to assess the aggregate effects of the various possible network-related problems mentioned here on the results of the with-BART/no-BART and with-BART/highway travel time comparisons. (No formal sensitivity analyses of the network travel times have been attempted.) However, it seems likely that the comparisons tend to over-state BART's impacts on improving travel times.

<u>Zones not Connected by Transit.</u> Comparison of travel times from the with-BART and no-BART transit networks is complicated by the fact that some zone pairs are not connected by transit in one or other (or both) of the

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*Zones 378, 393, 398, 400-405, 407-412, 417, 436-440.

transit networks, with the result that travel times between these unconnected zones are not defined. Comparisons between networks can, therefore, be made only for the set of zone pairs which are connected in both networks. In all analyses summarized in this working note, the set of zone pairs connected in common to the with-BART transit, no-BART transit, and highway networks is used as the basis for both with-BART/no-BART and with-BART/highway comparisons. Since all zone pairs are connected in the highway network, the set of connected zone pairs common to the with-BART and highway networks is generally larger than the set connected in common to the with-BART and no-BART networks. Thus, a larger set of zone pairs could be included in the former comparisons than in the latter. However, for consistency between the with-BART/no-BART and with-BART/highway comparisons, the same set of zone pairs is used in both.

Aside from possible network coding errors (as they may influence the specification of connected and unconnected zones), inclusion of only the common set of connected zones gives rise to the following complication in the analysis.

First, comparisons among the average travel times for trips to the various selected destination zones (or from the selected origin zones) are complicated because slightly different numbers of zone pairs may be commonly connected in each case. For example, as shown in Table 1, 223 zones in the 239-zone service area are connected to zone 144 (Oakland CBD) in both the with-BART and no-BART peak period networks, but only 218 zones are connected to zone 422 (San Francisco CBD). In the off-peak (Table 5), 189 zones are connected to zone 144 in both with-BART and no-BART networks, but only 184 zones are connected to zone 422.

The extent of the bias introduced into the analysis by considering only the set of commonly-connected zones is difficult to assess. But transit service is generally provided to a greater number of zones in the with-BART than in the no-BART transit networks. So, analysis of only the zone pairs common to both networks will tend to understate BART's accessibility improvements in the sense that the analysis excludes those zones which are not provided with transit service in the no-BART network, but are provided with service in the with-BART network. In other words, if no-BART transit travel times for the unconnected zones to be included in the analysis (by specifying some presumably very high travel time for the zones in question), a greater improvement in average travel times (with-BART over no-BART) would be shown than indicated by our analyses. However, it is likely that the resulting bias in the weighted accessibility analyses is generally small because the zone pairs excluded from our analysis are those for which trip volumes are small. (If it were otherwise, i.e., if a significant total trip market exists, transit service would presumably be provided in the no-BART network.)

Zone-to-Zone Trip Estimates. Further uncertainties are introduced into the analysis by the estimated zone-to-zone trip volumes used in the computation of the weighted average travel times. The work trip and shopping trip tables represent approximations of actual zone-to-zone volumes. Although the patterns of trips shown in the trip tables generally appear reasonable, it is possible that some of the estimates may differ significantly from actual current trip volumes, perhaps particularly for outlying suburban zones where large changes in land use activity patterns have occurred since 1965. In turn, these errors may give rise to distortions in the weighted average trip time estimates, although it is difficult to know how significant these distortions may be. Possible errors are evidenced by the large number of zone-to-zone trip volumes which are shown as zero in the trip tables. These are most evident for trips to outlying destination zones, for which in some cases there are relatively few zone pairs with non-zero entries in the trip tables. Note also that the analyses assume zero trips are made from a zone to itself; this may also introduce distortions, especially for large outlying suburban zones.

Findings

Tables 1 through 6 summarize the comparisons of average trip times among the with-BART transit, no-BART transit, and highway networks. With due regard to the caveats discussed in the preceding sections, the following general observations can be made on the results given in the tables.

There are obviously large differences between the unweighted and weighted results, with the weighted average trip times being much shorter than the unweighted trip times for all three networks. Based on comparison of the weighted averages, the with-BART network also shows generally smaller improvements relative to the no-BART network (and larger disadvantages relative to the highway network) than is suggested by comparison of the unweighted average times.

As shown in Tables 1 and 2, in the peak period, the with-BART transit system shows substantial improvements over the no-BART system for nearly all the zones listed. The greatest percentage improvements are from outlying suburban zones and to zones in central Berkeley, Oakland, and San Francisco. (The anomalous result for peak period travel to zone 104 (Concord) given in Table 1 is presumably explainable by errors or peculiarities in the networks and/or trip table, as discussed earlier.) Aside from the Concord result, the only exceptions to the rule of with-BART advantage over no-BART are for travel times from areas along the BART Richmond Line. From these areas the networks indicate that bus service in the no-BART network provides higher accessibility to the top 50 employment zones than does the with-BART transit system. This reflects the lack of direct BART service from the Richmond Line to San Francisco. The all-to-many summary of travel to the top 50 employment zones indicates a with-BART advantage of 5 minutes or 12% over the no-BART system.

Tables 5 and 6 show a generally similar pattern when off-peak travel times are compared for the with-BART and no-BART networks. Overall, the with-BART system shows only a slightly greater advantage in weighted average travel time (6 minutes or 16%) relative to the no-BART all-to-many average.

Although the networks indicate that the with-BART transit system provides appreciable travel time advantages over the no-BART transit system, Tables 3 and 4 show that peak-period travel times by automobile are still much less than times on the with-BART transit system in most cases. For many of the selected zones shown in Table 3, the with-BART network times to the top 50 employment zones average about twice as long as the equivalent highway travel times. Overall, the all-to-many summary shows automobile has an average travel time advantage of 14 minutes or 52%. The with-BART transit system is apparently most competitive with the automobile for travel to central San Francisco, Oakland, and Berkeley and from the more distant suburban areas.

Final Caveat

In conclusion, it should be repeated that the no-BART transit network assumed in this analysis is hypothetical, representing only one of many possible transit alternatives that could be assumed to form a "control" for assessing BART's impacts. Clearly, the results of the comparisons hinge on the assumptions represented by the no-BART network analyzed. If with-BART network travel times were to be compared with estimated times from a network representing some other hypothetical no-BART transit system--perhaps one with high-level express bus service--quite different conclusions might be reached.

Table 1

AVERAGE PEAK PERIOD TRAVEL TIMES TO SELECTED EMPLOYMENT ZONES
COMPARISON OF WITH-BART AND NO-BART TRANSIT NETWORKS
Origins: All 239 Zones in BART Service Area

Destination(s)			Unweighted Average Trip Times				Weighted Average Trip Times			
Zone Number	Employment Area	Zones Connected	No-BART Minutes	With-BART Minutes	Difference	Percent Difference	No-BART Minutes	With-BART Minutes	Difference	Percent Difference
104	Concord	219	120.4	78.4	42.0	34.9%	47.4	59.5	-11.9	-25.3%
117	Richmond	222	93.7	82.1	11.6	12.3	61.7	57.6	4.1	6.6
127	Berkeley Bayshore	224	72.6	65.0	7.6	10.5	47.2	44.6	2.6	5.5
129	Berkeley CBD	223	70.6	59.7	10.9	15.4	40.3	32.6	7.7	19.1
141	Port of Oakland	224	60.8	54.0	6.8	11.1	49.4	43.7	5.7	11.5
144	Oakland CBD	223	57.6	46.0	11.6	20.1	41.0	33.4	7.6	18.5
161	Oakland Fruitvale	224	73.4	53.6	19.8	26.9	48.7	34.9	13.8	28.3
176	San Leandro	224	79.9	72.6	7.3	9.1	49.4	45.8	3.6	7.3
357	South San Francisco	222	82.8	85.1	-2.3	-2.8	58.4	57.6	0.8	1.4
382	San Francisco Rincon	223	57.4	48.5	8.9	15.5	48.2	42.3	5.9	12.2
385	San Francisco Mission	224	65.8	56.7	9.1	13.8	39.8	35.7	4.1	10.3
422	San Francisco CBD	218	52.8	42.8	10.0	19.0	35.6	31.4	4.2	11.5
430	San Francisco Nob Hill	217	63.5	54.4	9.1	14.3	43.5	40.0	3.5	8.0
Top 50 Employment Zones		209 (Average)	71.8	59.8	12.0	16.6%	45.6	40.2	5.4	11.9%

Note: All comparisons are for the set of zone pairs connected in common for the with-BART transit, no-BART transit, and highway networks. Weighting factors used in computing weighted average trip times are estimated numbers of zone-to-zone work trips.

Table 2

AVERAGE PEAK PERIOD TRAVEL TIMES FROM SELECTED RESIDENTIAL ZONES
COMPARISON OF WITH-BART AND NO-BART TRANSIT NETWORKS
Destinations: Top 50 Employment Zones in 239-Zone BART Service Area

Origin			Unweighted Average Trip Times				Weighted Average Trip Times			
Zone Number	Residential Area	Zones Connected	No-BART Minutes	With-BART Minutes	Difference	Percent Difference	No-BART Minutes	With-BART Minutes	Difference	Percent Difference
74	Pittsburg	47	122.7	120.7	2.0	1.6%	95.4	94.7	0.7	0.8%
99	Walnut Creek	46	73.3	61.6	12.2	16.7	60.3	49.0	11.3	18.8
118	Richmond	47	67.5	62.8	4.7	7.0	42.7	41.1	1.6	3.7
120	El Cerrito	47	68.6	57.6	11.0	16.1	51.1	58.9	-7.8	-15.3
130	U.C. Berkeley	45	58.7	50.8	7.9	13.4	61.8	66.4	-4.6	- 7.4
136	North Oakland	47	48.6	47.4	1.2	2.5	32.1	32.2	-0.1	- 0.2
137	Oakland Rockridge	47	52.8	44.4	8.4	15.9	33.1	30.0	3.1	9.4
138	Oakland MacArthur	47	45.4	41.6	3.8	8.4	29.6	27.9	1.7	5.7
159	Oakland Fruitvale	47	55.2	49.2	6.0	10.9	39.3	36.9	2.4	6.1
192	South Hayward	47	102.7	64.1	38.6	37.5	72.2	46.0	26.2	36.2
203	Fremont	47	122.8	69.1	53.7	43.7	102.7	56.1	46.6	45.4
212	Livermore	47	123.6	110.2	13.4	10.8	92.6	92.5	0.1	0.1
347	Pacifica	47	96.5	59.0	37.5	38.9	79.2	49.4	29.8	37.6
363	Daly City	47	82.5	65.8	16.7	20.2	60.2	49.5	10.7	17.7
394	San Francisco Twin Peaks	47	65.3	51.4	13.9	21.2	42.3	32.1	10.2	24.1
406	San Francisco Clement	47	64.6	57.1	7.5	11.6	37.5	35.6	1.9	5.1
440	San Francisco Marina	47	58.9	51.7	7.2	12.2	33.8	30.7	3.1	9.2

Note: All comparisons are for the set of zone pairs connected in common for the with-BART transit, no-BART transit, and highway networks. Weighting factors used in computing weighted average trip times are estimated numbers of zone-to-zone work trips.

Table 3

AVERAGE PEAK PERIOD TRAVEL TIMES TO SELECTED EMPLOYMENT ZONES
COMPARISON OF WITH-BART AND HIGHWAY NETWORKS
Origins: All 239 Zones in BART Service Area

Destination(s)			Unweighted Average Trip Times				Weighted Average Trip Times			
Zone Number	Employment Area	Zones Connected	Highway Minutes	With-BART Minutes	Difference	Percent Difference	Highway Minutes	With-BART Minutes	Difference	Percent Difference
104	Concord	219	55.1	78.4	-23.3	-42.3%	27.0	59.5	-32.5	-120.1%
117	Richmond	222	42.3	82.1	-39.8	-93.9	27.6	57.6	-30.0	-108.8
127	Berkeley Bayshore	224	37.8	65.0	-27.2	-72.0	24.8	44.6	-19.8	- 80.1
129	Berkeley CBD	223	44.2	59.7	-15.5	-34.9	24.8	32.6	- 7.8	- 31.5
141	Port of Oakland	224	43.8	54.0	-10.2	-23.3	35.6	43.7	- 8.1	- 22.7
144	Oakland CBD	223	35.4	46.0	-10.6	-30.0	26.5	33.4	- 6.9	- 26.0
161	Oakland Fruitvale	224	34.5	53.6	-19.1	-55.5	20.6	34.9	-14.3	- 69.5
176	San Leandro	224	42.1	72.6	-30.5	-72.6	23.3	45.8	-22.5	- 96.5
357	South San Francisco	222	51.2	85.1	-33.9	-66.2	29.2	57.6	-28.4	- 97.2
382	San Francisco Rincon	223	34.8	48.5	-13.7	-39.4	29.2	42.3	-13.1	- 44.8
385	San Francisco Mission	224	39.0	56.7	-17.7	-45.4	20.2	35.7	-15.5	- 76.6
422	San Francisco CBD	218	38.6	42.8	- 4.2	-11.0	25.7	31.4	- 5.7	- 22.2
430	San Francisco Nob Hill	217	40.1	54.4	-14.3	-35.6	26.9	40.0	-13.1	- 48.8
Top 50 Employment Zones		209 (Average)	41.9	59.8	-17.9	-42.9%	26.5	40.2	-13.7	- 52.0%

Note: All comparisons are for the set of zone pairs connected in common for the with-BART transit, no-BART transit, and highway networks. Weighting factors used in computing weighted average trip times are estimated numbers of zone-to-zone work trips.

Table 4

AVERAGE PEAK PERIOD TRAVEL TIMES FROM SELECTED RESIDENTIAL ZONES
COMPARISON OF WITH-BART AND HIGHWAY NETWORKS
Destinations: Top 50 Employment Zones in 239-Zone BART Service Area

Origin			Unweighted Average Trip Times				Weighted Average Trip Times			
Zone Number	Residential Area	Zones Connected	Highway Minutes	With-BART Minutes	Difference	Percent Difference	Highway Minutes	With-BART Minutes	Difference	Percent Difference
74	Pittsburg	47	75.6	120.7	-45.1	-59.8%	56.4	94.7	-38.3	- 68.0%
99	Walnut Creek	46	62.5	61.1	1.4	2.3	55.3	49.0	6.3	11.3
118	Richmond	47	46.6	62.8	-16.2	-34.7	26.7	41.1	-14.4	- 53.8
120	El Cerrito	47	36.7	57.6	-20.9	-56.9	26.6	58.9	-32.3	-121.5
130	U.C. Berkeley	45	41.5	50.8	- 9.3	-22.3	49.9	66.4	-16.5	- 33.0
136	North Oakland	47	30.9	47.4	-16.5	-53.3	20.9	32.2	-11.3	- 54.2
137	Oakland Rockridge	47	30.6	44.4	-13.8	-44.9	19.6	30.0	-10.4	- 53.0
138	Oakland MacArthur	47	29.1	41.6	-12.5	-43.1	19.1	27.9	- 8.8	- 46.3
159	Oakland Fruitvale	47	34.6	49.2	-14.6	-42.0	25.5	36.9	-11.4	- 44.9
192	South Hayward	47	53.6	64.1	-10.5	-19.6	34.7	46.0	-11.3	- 32.5
203	Fremont	47	67.4	69.1	- 1.7	- 2.5	53.1	56.1	- 3.0	- 5.7
212	Livermore	47	66.9	110.2	-43.3	-64.7	55.5	92.5	-37.0	- 66.8
347	Pacifica	47	42.0	59.0	-17.0	-40.4	28.5	49.4	-20.9	- 73.1
363	Daly City	47	43.0	65.8	-22.8	-53.0	31.0	49.5	-18.5	- 59.8
394	San Francisco Twin Peaks	47	36.6	51.4	-14.8	-40.3	22.6	32.1	- 9.5	- 42.1
406	San Francisco Clement	47	41.7	57.1	-15.4	-36.8	25.3	35.6	-10.3	- 40.5
440	San Francisco Marina	47	36.6	51.7	-15.1	-41.3	21.6	30.7	- 9.1	- 42.3

Note: All comparisons are for the set of zone pairs connected in common for the with-BART transit, no-BART transit, and highway networks. Weighting factors used in computing weighted average trip times are estimated numbers of zone-to-zone work trips.

Table 5

AVERAGE OFF PEAK TRAVEL TIMES TO SELECTED SHOPPING ZONES
COMPARISON OF WITH-BART AND NO-BART TRANSIT NETWORKS
Origins: All 239 Zones in BART Service Area

Destination(s)			Unweighted Average Trip Times				Weighted Average Trip Times			
Zone Number	Shopping Area	Zones Connected	No-BART Minutes	With-BART Minutes	Difference	Percent Difference	No-BART Minutes	With-BART Minutes	Difference	Percent Difference
104	Concord	163	143.9	74.8	69.1	48.0%	64.2	55.3	8.9	13.9%
129	Berkeley CBD	189	69.1	57.0	12.1	17.5	27.7	27.2	0.5	1.8
144	Oakland CBD	189	61.1	43.6	17.5	28.6	37.6	30.1	7.5	19.9
161	Oakland Fruitvale	190	71.3	51.1	20.2	28.3	38.4	29.5	8.9	23.2
185	Hayward	188	99.5	65.7	33.8	34.0	48.6	36.3	12.3	25.3
377	San Francisco Stonestown	190	72.4	59.9	12.5	17.3	34.9	31.1	3.8	10.9
387	San Francisco Mission	190	62.4	45.9	16.5	26.4	24.6	24.4	0.2	0.8
422	San Francisco CBD	184	53.9	40.2	13.7	25.4	31.2	27.4	3.8	12.2
Top 50 shopping zones		168 (Average)	75.2	57.0	18.2	24.2%	40.6	34.2	6.4	15.7%

Note: All comparisons are for the set of zone pairs connected in common for the with-BART transit, no-BART transit, and highway networks. Weighting factors used in computing weighted average trip times are estimated number of zone-to-zone shopping trips.

Table 6

AVERAGE OFF-PEAK TRAVEL TIMES FROM SELECTED RESIDENTIAL ZONES
COMPARISON OF WITH-BART AND NO-BART TRANSIT NETWORKS
Destinations: Top 50 Shopping Zones in 239-Zone BART Service Area

Origin			Unweighted Average Trip Times				Weighted Average Trip Times			
Zone Number	Residential Area	Zones Connected	No-BART Minutes	With-BART Minutes	Difference	Percent Difference	No-BART Minutes	With-BART Minutes	Difference	Percent Difference
74	Pittsburg	0	--	--	--	--	--	--	--	--
99	Walnut Creek	44	105.7	65.5	40.2	38.0%	70.6	31.6	39.0	55.2%
118	Richmond	45	78.8	67.3	11.5	14.5	35.6	41.4	- 5.8	-16.2
120	El Cerrito	45	71.7	64.1	7.6	10.5	31.4	26.8	4.6	14.6
130	U.C. Berkeley	44	63.0	53.4	9.6	15.2	32.5	29.3	3.2	9.8
136	North Oakland	45	55.3	50.7	4.6	8.3	25.5	27.2	- 1.7	6.7
137	Oakland Rockridge	45	60.6	51.9	8.7	14.4	28.3	26.0	2.3	8.1
138	Oakland MacArthur	45	50.5	44.5	6.0	11.9	20.5	20.9	- 0.4	- 2.0
159	Oakland Fruitvale	44	65.3	53.3	12.0	18.4	31.4	31.8	- 0.4	- 1.3
192	South Hayward	42	126.7	64.9	61.8	48.8	58.6	46.3	12.3	21.0
203	Fremont	0	--	--	--	--	--	--	--	--
212	Livermore	0	--	--	--	--	--	--	--	--
347	Pacifica	0	--	--	--	--	--	--	--	--
363	Daly City	43	90.5	65.2	25.3	27.9	64.2	44.8	19.4	29.9
394	San Francisco Twin Peaks	45	63.6	47.9	15.7	24.7	30.0	23.3	6.7	22.3
406	San Francisco Clement	45	67.3	57.6	9.7	14.4	33.4	31.5	1.9	5.6
440	San Francisco Marina	45	57.4	51.0	6.4	11.1	24.2	23.6	0.6	2.5

Note: All comparisons are for the set of zone pairs connected in common for the with-BART transit, no-BART transit, and highway networks. Weighting factors used in computing weighted average trip times are estimated numbers of zone-to-zone shopping trips.

APPENDIX

TOP 50 TOTAL EMPLOYMENT ZONES IN 239-ZONE GREATER BART SERVICE AREA

TOP 50 LOCAL-SERVING EMPLOYMENT ZONES IN 239-ZONE GREATER BART SERVICE AREA

Notes

Zones are as defined by the MTC 440 regional traffic zone system.

Total employment and local-serving employment estimates are from: Provisional Series 3 Projections, Population, Housing, Employment, and Land Uses, San Francisco Bay Region, Association of Bay Area Governments, March 2, 1977.

TOP 50 TOTAL EMPLOYMENT ZONES IN THE 239-ZONE GREATER BART SERVICE AREA

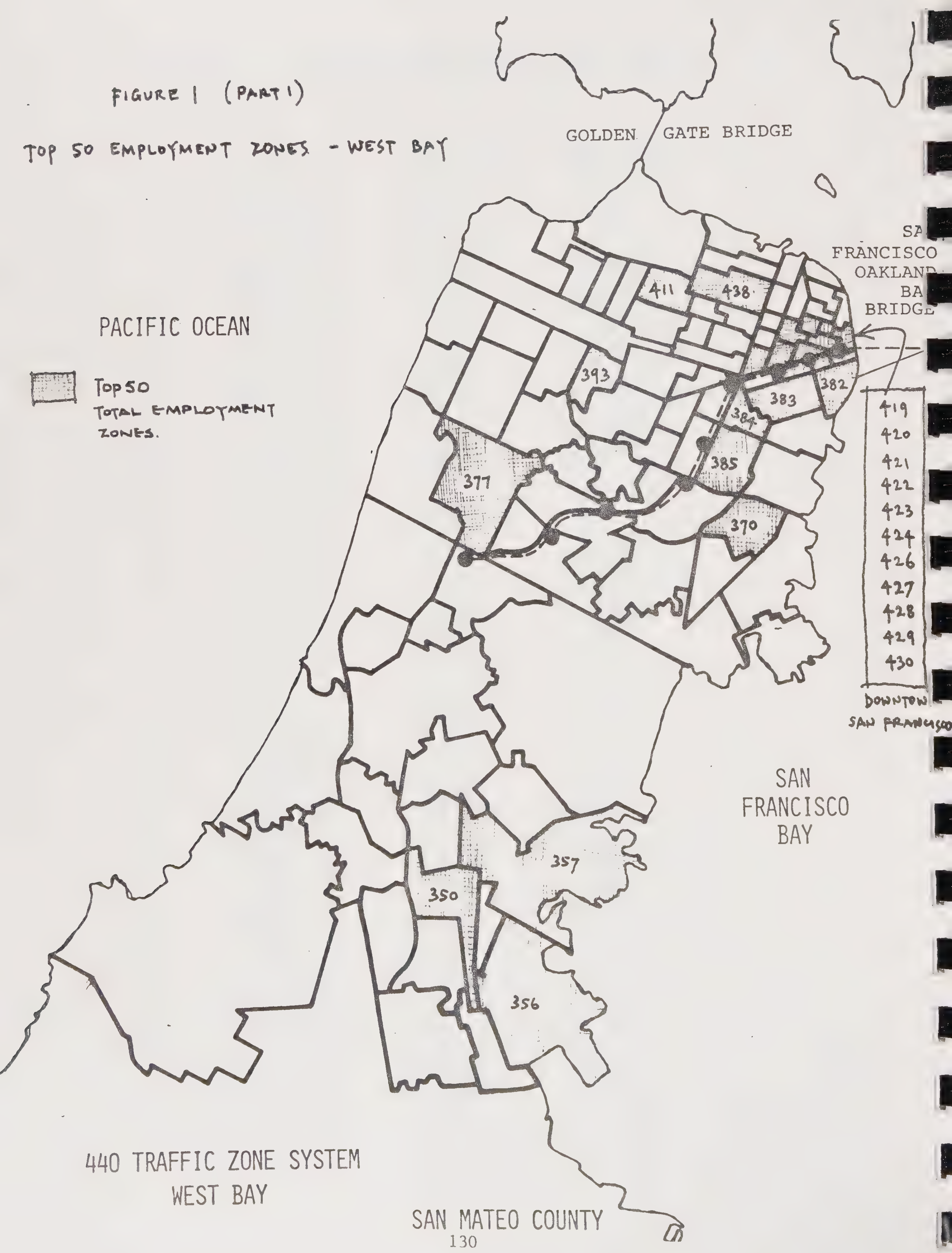
Rank	Zone Number	Total Employment	County
1	422	43,889	San Francisco
2	421	42,933	San Francisco
3	144	29,139	Alameda
4	429	20,857	San Francisco
5	356	20,517	San Mateo
6	382	20,109	San Francisco
7	428	19,604	San Francisco
8	424	18,418	San Francisco
9	383	18,417	San Francisco
10	104	18,074	Contra Costa
11	141	17,381	Alameda
12	426	16,701	San Francisco
13	427	15,990	San Francisco
14	161	14,161	Alameda
15	129	13,693	Alameda
16	127	13,487	Alameda
17	357	13,363	San Mateo
18	130	13,173	Alameda
19	430	12,719	San Francisco
20	117	12,541	Contra Costa
21	139	11,859	Alameda
22	98	11,336	Contra Costa
23	190	11,219	Alameda
24	176	11,175	Alameda
25	170	11,041	Alameda
26	423	10,894	San Francisco
27	420	10,496	San Francisco
28	143	10,036	Alameda
29	370	9,955	San Francisco
30	175	9,684	Alameda
31	162	9,387	Alameda
32	145	9,376	Alameda
33	133	9,306	Alameda
34	135	9,068	Alameda
35	109	8,975	Contra Costa
36	74	8,952	Contra Costa
37	142	8,819	Alameda
38	385	8,729	San Francisco
39	216	8,676	Alameda
40	377	8,631	San Francisco
41	350	8,377	San Mateo
42	411	8,327	San Francisco
43	172	8,280	Alameda
44	189	8,218	Alameda
45	171	8,088	Alameda
46	185	8,009	Alameda
47	384	8,004	Alameda
48	438	7,767	San Francisco
49	419	7,415	San Francisco
50	393	7,027	San Francisco

TOP 50 LOCAL-SERVING EMPLOYMENT ZONES
IN 239-ZONE GREATER BART SERVICE AREA

Rank	Zone Number	Local-Serving Employment	County
1	422	28,657	San Francisco
2	421	19,179	San Francisco
3	144	17,273	Alameda
4	104	11,699	Contra Costa
5	423	9,617	San Francisco
6	428	9,549	San Francisco
7	129	9,188	Alameda
8	98	8,931	Contra Costa
9	139	8,039	Alameda
10	424	8,003	San Francisco
11	426	7,944	San Francisco
12	383	7,629	San Francisco
13	350	7,198	San Mateo
14	145	7,003	Alameda
15	438	6,487	San Francisco
16	185	6,416	Alameda
17	427	6,404	San Francisco
18	161	6,394	Alameda
19	190	6,375	Alameda
20	419	6,358	San Francisco
21	109	6,140	Contra Costa
22	420	6,133	San Francisco
23	143	5,805	Alameda
24	412	5,699	San Francisco
25	430	5,426	San Francisco
26	385	5,336	San Francisco
27	387	5,203	San Francisco
28	142	5,002	Alameda
29	113	4,964	Contra Costa
30	175	4,840	Alameda
31	377	4,660	San Francisco
32	166	4,629	Alameda
33	176	4,621	Alameda
34	411	4,437	San Francisco
35	395	4,229	San Francisco
36	212	3,998	Alameda
37	353	3,966	San Mateo
38	74	3,947	Contra Costa
39	358	3,926	San Mateo
40	363	3,848	San Mateo
41	395	3,752	San Francisco
42	386	3,745	San Francisco
43	127	3,741	Alameda
44	117	3,738	Contra Costa
45	159	3,716	Alameda
46	416	3,686	San Francisco
47	434	3,677	San Francisco
48	196	3,676	Alameda
49	116	3,666	Contra Costa
50	397	3,638	San Francisco

FIGURE 1 (PART 1)

TOP 50 EMPLOYMENT ZONES - WEST BAY



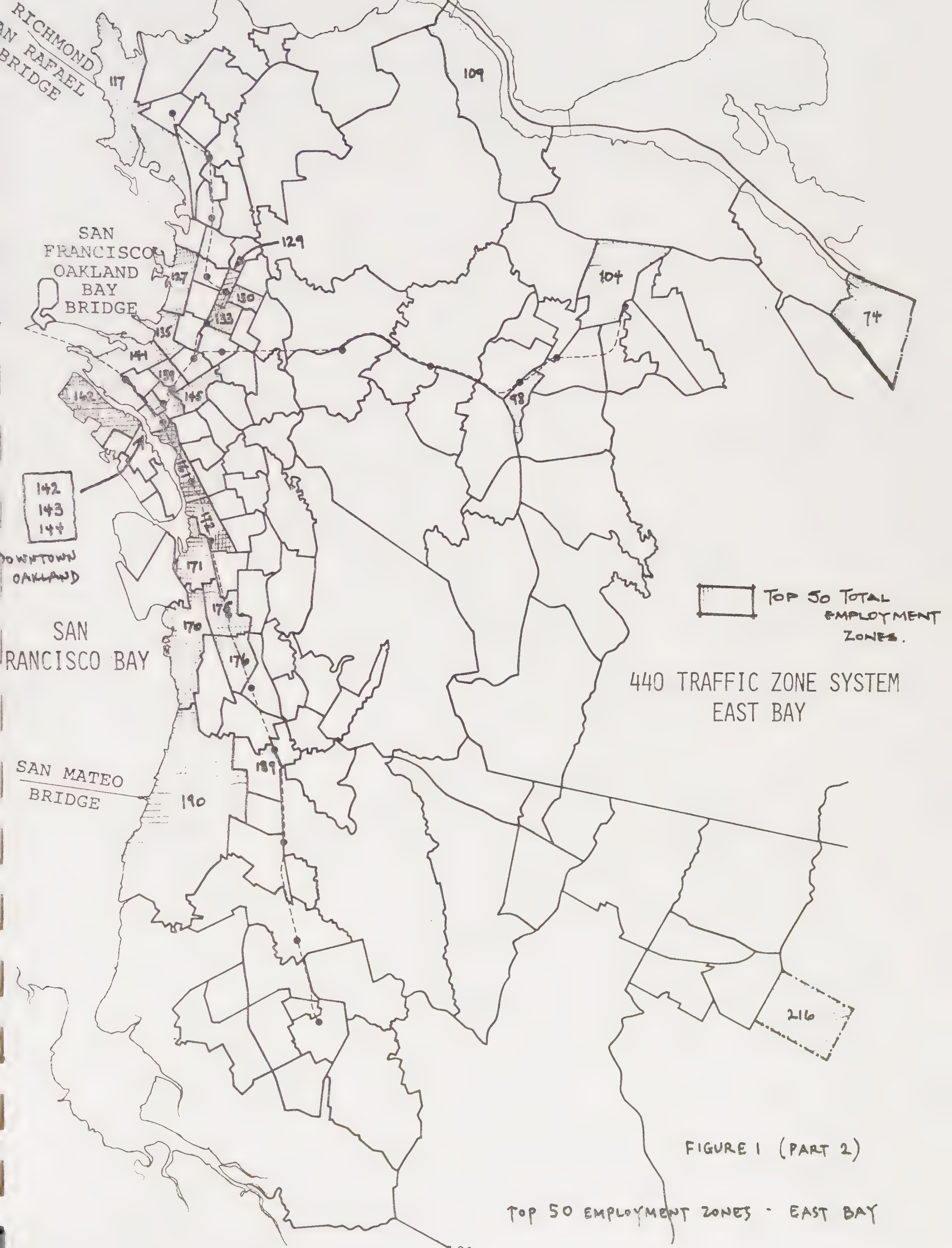


FIGURE 1 (PART 2)

TOP 50 EMPLOYMENT ZONES - EAST BAY

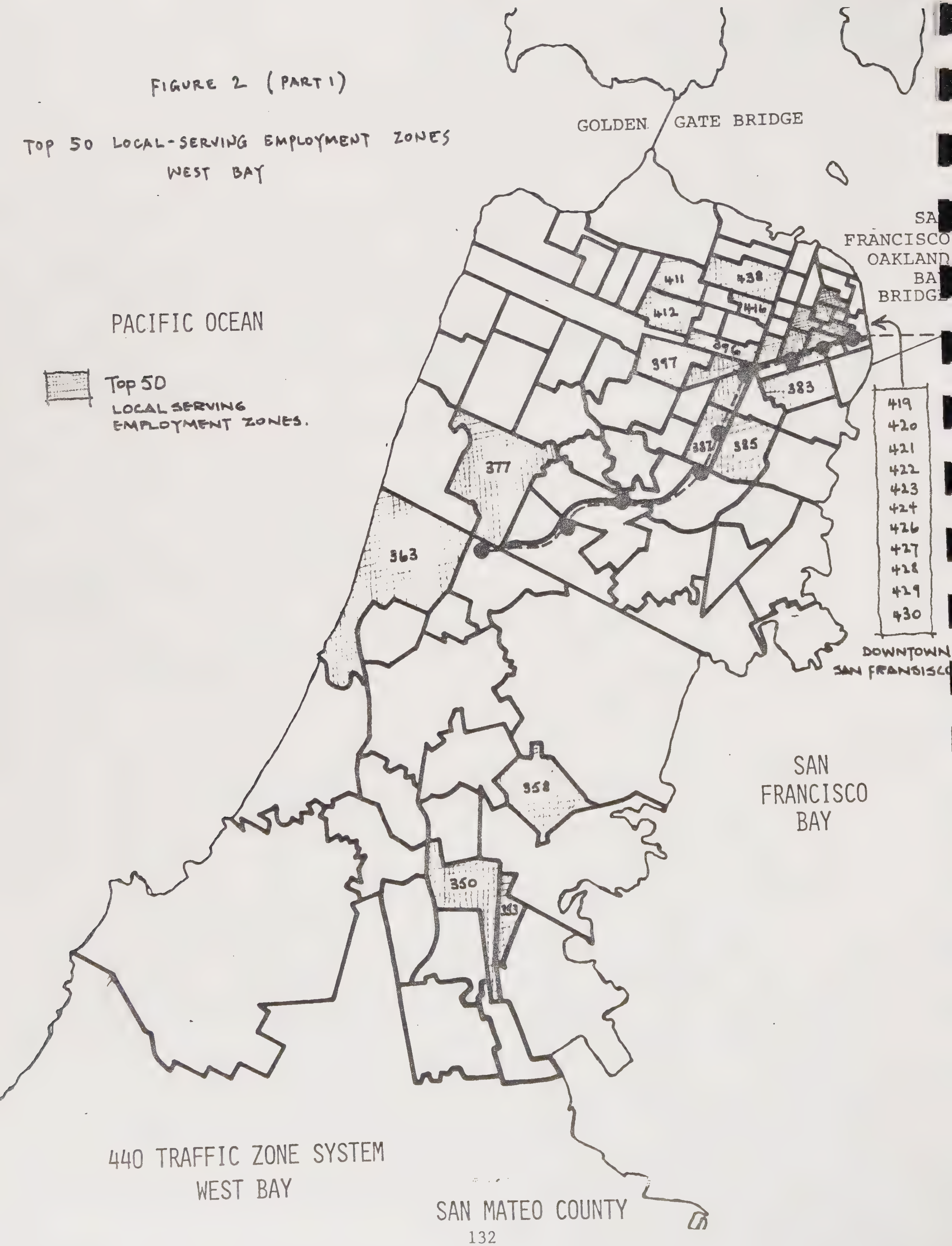


FIGURE 2 (PART 1)
TOP 50 LOCAL-SERVING EMPLOYMENT ZONES
WEST BAY
GOLDEN GATE BRIDGE
SAN FRANCISCO OAKLAND BAY BRIDGE
PACIFIC OCEAN
Top 50
LOCAL SERVING
EMPLOYMENT ZONES.
411
438
412
416
396
397
383
377
387
385
363
419
420
421
422
423
424
426
427
428
429
430
DOWNTOWN
SAN FRANSISCO
SAN
FRANCISCO
BAY
358
350
353
440 TRAFFIC ZONE SYSTEM
WEST BAY
SAN MATEO COUNTY

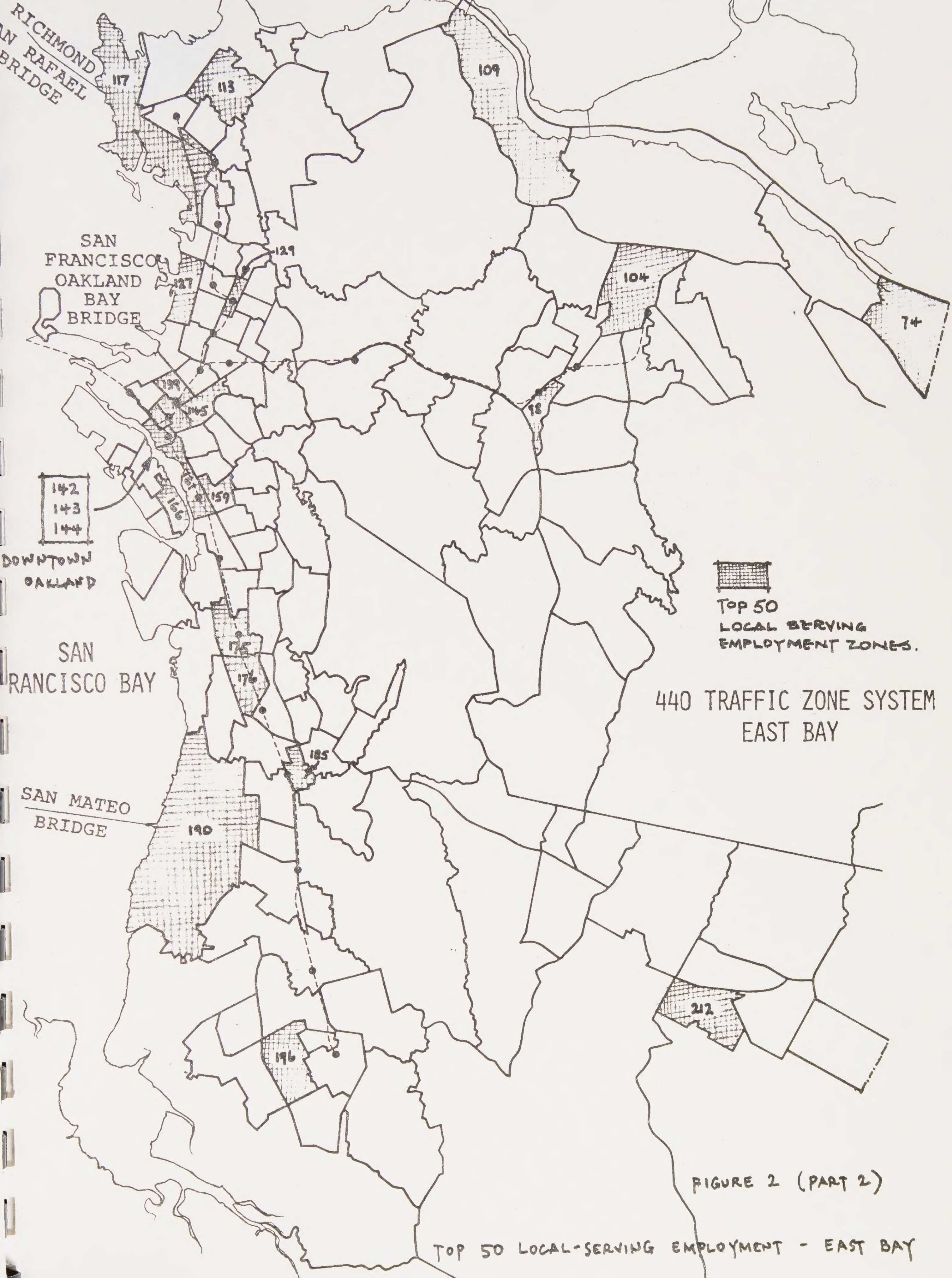


FIGURE 2 (PART 2)

TOP 50 LOCAL-SERVING EMPLOYMENT - EAST BAY